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SOUTH AMERICAN LEAF BLIGHT

A REVIEW OF THE LITERATURE RELATING TO ITS DEPREDATIONS IN SOUTH AMERICA, ITS THREAT TO THE FAR EAST, AND THE METHODS AVAILABLE FOR ITS CONTROL

By
R.N. HILTON

The life history of Dothidella ulei is described, and an account given of the part this fungus has played in preventing a tropical American rubber plantation industry from being established. The methods of control involving quarantine, eradication, spraying, and breeding resistant material are discussed, with special emphasis on the cooperative work between the United States Department of Agriculture and Latin American countries. An assessment is made of the danger presented to the rubber growing areas of Asia, all of which are free from South American leaf blight, and an account given of efforts in Asia to exclude the disease, to eradicate it if an outbreak should occur, and to control it if eradication were to fail. All literature references used in preparing the review are listed at the end.

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I INTRODUCTION

There have been many references to South American leaf blight published since 1910, when it was first recognised as a disease of economic importance. As the severity of this disease in tropical America has been realised, increasing emphasis has been given to work on control measures. The literature of the last ten years shows the fruitful results of the close cooperation between the United States Department of Agriculture and the agricultural departments of most of the tropical American countries. Before the second world war little had been published in the far eastern countries, and no special precautions against South American leaf blight taken as the disease was felt to be too remote to cause concern. Immediately after the war the position changed. There was a great expansion in world air traffic, increasing the possibility of the disease being introduced; meanwhile research in America had laid a foundation on which preventative measures could be based. Thus the danger had become greater, but so had the development of means of defence.

Those responsible for phytosanitary protection of the rubber industry of the far east concentrated on preparing means to combat it, in consultation with workers in America. Now that preparatory measures have been taken, it is opportune to publish an account of the disease and an estimate of the danger it presents to the rubber industry of the east. The body of this publication is a review of literature published in America on the disease, and an account of the work of the Pathological Division of the Rubber Research Institute of Malaya. The position at the start of this work is given by R.A. Altson, then Head of this Division, in a hitherto unpublished memorandum dated 4 February 1948 and quoted in full in the *Appendix*. Details of introductions of resistant material and its projected use are to be given in a subsequent communication by the Botanical Division of the Rubber Research Institute.

The 1948 memorandum is given in full because it initiated many of the projects, the following up of which is reported in the present communication. It was not the first warning to the

eastern rubber industry (BELGRAVE 1921; WEIR 1929) but it drew attention to the greater dangers that had come with increased air transport and proposed systematically worked out defence measures.

The Board of the Rubber Research Institute considered Mr Altson's memorandum at their meeting on 26 February 1948 and approved action being initiated by the Director on his arrival in Britain on leave.

In response to a request from the London Advisory Committee for Rubber Research (Ceylon and Malaya), the Colonial Office received a deputation on the 12 July on the subject of South American leaf disease of rubber and its threat to the rubber growing industry in Malaya and Ceylon (BURGESS 1948). The Committee was represented by Mr P.J. Burgess (Chairman), Dr S.P. Wiltshire and Mr J.A. Nelson (Secretary), together with Mr C.E.T. Mann.

The delegation explained that although there were as yet no signs of the South American leaf blight appearing in the far east, the disease was one which constituted a very severe danger to rubber trees wherever it appeared, as was evidenced by the facts in South America. Current conditions, including in particular the increasing volume of air traffic, made it necessary that those who were concerned with the well being of rubber in the far east should give very serious thought to such steps as were required to prevent the spread of the disease to that area, and to be prepared in advance with measures to be taken should it appear there.

The principal lines of action considered were as follows:

i Preventing entry of material (including living material of *Hevea* spp. and also dead material in the form of packing or potting compost) that might carry the disease. The Colonial Office undertook to consider the possibility of a request being made to all air lines concerned to refuse to carry material which might convey the infection.

ii Strengthening legislation in far eastern territories to prevent its introduction and to provide for early detection and prompt eradication measures should the disease ever appear. The Colonial Office undertook to consider by what means agreement could be reached with the other territories concerned for introducing joint measures to prevent importation into the far east of material likely to carry disease. The proposed phytosanitary convention for Africa south of the Sahara, which was to be discussed at a forthcoming conference, was suggested as a useful guide.

iii Breeding disease resistant material. This was dependent upon an infected area being available where each series of crosses could be tested. It was mentioned that disease resistant material was available in the western

hemisphere, but that there were restrictions on its export to the east, and the agreement for this restriction had been entered into also by Trinidad. It was not, therefore, possible at that time to obtain the resistant material required for breeding.

iv Experiments to discover the effect on yield when high yielding clones were top budded with disease resistant strains.

v A publicity campaign in Malaya to warn planters of the danger of the disease and to acquaint them with its appearance.

At a second meeting at the Colonial Office on 2 September 1948, progress under the above five headings was reported. Both the Principal of the Imperial College of Tropical Agriculture (Mr H.J. Page) and the Director of Agriculture, Trinidad, (Mr Leach) were present, and approved of the Rubber Research Institute of Malaya establishing a Trinidad substation for testing eastern clones should it prove impossible to obtain resistant material developed by the U.S. Department of Agriculture Cooperative Rubber Plantation Project. Subsequently, as recounted in the following pages, the American resistant clones were obtained by exchange for high yielding eastern material.

The nine sections of this publication describe first the disease itself. Then follows an account of the establishment of the American plantations, the damage that ensued from leaf blight, and the measures taken to prevent this damage. The history of the establishment of the plantations in the far east is given, the damage that might ensue from introduction of *Dothidella ulei* discussed, and finally the three main lines of defence described in turn.

II THE DISEASE

The information here recorded is taken primarily from the publications of STAHEL (1917) and LANGFORD (1945). Stahel worked at the Department of Agriculture, Paramaribo, Surinam, where leaf blight was first recorded in 1910 (DROST 1910). Langford worked at the United States Department of Agriculture Cooperative Rubber Plant Field Station, Turrialba, Costa Rica, where leaf blight appeared in 1935.

GEOGRAPHICAL DISTRIBUTION

The natural range of South American leaf blight is taken to be the area in which species of *Hevea* are indigenous—the Amazon Basin. It has extended its range in continental America wherever *Hevea* rubber is grown, but has not appeared in the Carribean Islands other than Trinidad nor in Africa or Asia (COMMONWEALTH MYCOLOGICAL INSTITUTE 1944, 1948). The reported extremities of its range are El Palmar, in Southern Mexico at latitude 18°N, and Ilheos, in the Brazilian state of Bahia, at latitude 15°S. The first collections of diseased material were made by Ule on the upper Amazon.

ECONOMIC IMPORTANCE

Leaf blight was a major factor in preventing the establishment of a plantation rubber industry in the Americas (KLIPPERT 1941). In its importance it must rank with coffee rust (*Hemileia vastatrix*), an Old World disease which has lost the Arabian coffee industry to the New.

SYMPTOMS

Leaf disease symptoms always vary with the age of leaf attacked, and this is particularly marked in *Hevea* in which the leaves pass through a series of well defined stages. Initiating the phase of growth the terminal bud extends to form a stem 6 inches to 1 foot long carrying a flush of 15-20 leaves at the apex. The young leaves have each of the three leaflets folded downwards and inwards. The whole flush is brown and shining, being very rich in anthocyanin pigments at this stage. In a few days the leaves open out, still hanging vertically. The anthocyanin disappears, the colour changing through dull brown to green. Finally the cuticle hardens and the leaves assume a horizontal position.

The reaction of a leaf of any given age depends on the intensity of attack. A heavy attack on very young leaves up to ten days old causes them to be covered with olive green sporing masses within five to eight days of infection and the leaflets are rapidly shed followed by the petioles a few days later. A less heavy attack leads to loss of a few leaflets and distortion of the remainder, the distorted portions becoming covered with the olive green spores.

On an older leaf that has arrived at the dull brown stage, (twelve - twenty days old) the infection takes the form of dull, velvety looking spots, olive to greyish green. When matured such spotted leaves are ragged and shotholed. On them develops the highly characteristic secondary stage which consists of a series of rings of hard charcoal-like bodies round the margins of old spots.

Once the leaves have a hardened cuticle they are no longer susceptible to infection although, if infected when young, such mature leaves may continue to produce the disease.

Immature tissue of stems, flowers and fruits is as liable to attack as that of the leaves.

ANATOMY OF THE CAUSAL ORGANISM

The following descriptions of the three forms of the causal fungus are taken from PETCH (1921).

Dothidella Ulei, P. Henn. — Stromata caespitose, erumpent, ovoid, black, rugulose, about 0.3-3 mm. diameter; perithecia few, ovoid; asci clavate, eight-spored, 50-80 × 10-16 μ, spores subdistichous; paraphyses present; spores oblongo-clavate, hyaline, one-septate, scarcely constricted, 13-20 μ. On leaves of *Hevea brasiliensis,* Amazon valley. According to Griffon and Maublanc [*] the stromata sometimes contain pycnidial cavities, with cylindric pycnospores, inflated at the ends, 4-5 μ long, on flask-shaped

[*] GRIFFIN and MAUBLANC (1913)

basidia. Conidial stage = *Fusicladium macrosporum* Kuyper. Pycnidial stage = *Aposphaeria Ulei* P. Henn.

Aposphaeria Ulei P. Henn. — Pycnidia black, carbonaceous, almost spherical or ovoid, erumpent, appearing completely superficial, scattered or crowded, papillate, about 120-160 μ diameter; spores cylindric or fusoid, straight or somewhat curved, hyaline, 6-10 × 0.8-1 μ, containing two or three small guttae. On leaves of *Hevea brasiliensis*, with *Dothidella Ulei and Catacauma Huberi.*

Fusicladium macrosporum, Kuyper. — Spots amphigenous, olivaceous, becoming grey in the centre; at first, 3-10 mm. diameter, then greater, irregular, with confluent multiseptate hyphae forming a pseudostroma on old spots; conidiophores erumpent, unicellular, sometimes uniseptate, subglobose at the base, 40-70 μ high, 4-7 μ diameter, brown, often flexuose; conidia acrogenous, ellipsoid, ends obtuse, or obclavate-pyriform, irregular, 30-55 × 8-12 μ, finally uniseptate, scarcely constricted, dark brown.

The original descriptions of *Dothidella ulei* and *Aposphaeria ulei* are in German (HENNINGS 1904a) and Latin (HENNINGS 1904b). Those of *Fusicladium macrosporum* are in German, with Latin diagnosis (KUYPER 1911), Dutch (KUYPER 1912) and English (KUYPER 1913).

A description of all three forms was given in French by CAYLA (1913), who considered them to belong to the same fungus. This view was endorsed by VINCENS (1915) after his studies at Belem, and by PETCH (1914). STAHEL (1917), went into the anatomy and morphology in considerable detail, finally creating a new genus *Melanopsammopsis* for the perithecial form. He demonstrated anatomically the identity of this fungus with the pycnidial form *Aposphaeria heveae* P. Henn. Stahel refers to the conidial form as the '*Scolecotrichum* stage'.

Langford states that the leaf blight conidia vary greatly in colour, shape and size. They may be one or two celled, 5-8 μ wide, and 12μ -30 μ long with a mean of 4 μ × 13 μ. The asci are cylindrical, 65-85 × 12-15 μ, and eight spored. He quotes no dimensions for the pycnidia and pycnidiospores. As these structures are non-infective he thought it probable that they represent spermogonia and spermatia.

PHYSIOLOGY OF THE CAUSAL ORGANISM

GROWTH IN CULTURE—Langford was the first to succeed in growing *Dothidella ulei* in culture. He used 0.5% malt agar, each litre of which contained a decoction of 50 grams of young hevea leaves. The colonies were up to 5 mm in diameter and sporing freely when four weeks old.

Spore germination. Both ascospores and conidia will produce germ tubes of several times the spore length when held in water at 24°C for ten hours.

VIABILITY—Both conidia and ascospores were found by Langford to remain viable for several days after release from the host. There was high percentage germination after 3 days at 80°F and 70% RH, but it was low after 7 days under these conditions. However, after 7 days exposure to wind and sun on the surface of susceptible leaves, spores were still able to infect the leaves if the humidity was raised. There is no information on the longevity of mycelium either free, in twig lesions, or in

stromatic tissue. According to WEIR (1926) fertile perithecia persist on three year old stems but this has not been confirmed by later work.

PATHOGENICITY

Formal proof that *Dothidella ulei* was the cause of South American leaf blight came with Langford's isolation and growth of the fungus in culture and the subsequent infection of healthy plants with the conidia produced.

SPORULATION

A conidium may originate a discernible lesion within 5-6 days, which may be sporing heavily within another 4 days and continue to do so for a few weeks until ceasing after 2-3 months. After this period ascospores, from the perithecia which begin to form, become the functional spores. Perithecia on leaves 3-4 months old produce abundant ascospores, although in minute numbers compared with the conidia formed on the young leaves.

DISSEMINATION

Local dissemination within adjacent trees is principally by rain and dew splash. Spread across open spaces is by wind, spores travelling many miles by this means and remaining viable. Ascospores may play a more important part than conidia in long distance spread by wind.

INFECTION

A conidium requires 8-10 hours of moisture on the leaf surface in order to germinate and penetrate. It is incapable of penetrating the hardened cuticle of a leaf two weeks old.

HOST REACTION

Reaction to a heavy infection may consist of shedding the leaf, but lighter infections lead to lesions being delimited by a thin black margin. Sometimes the whole of the centre of the lesion drops out to form a shot hole.

DISEASE RESISTANCE

Langford has stressed that resistance may be manifested by inhibition of sporulation as well as by prevention of damage (LANGFORD 1943 page 19). The classes he has proposed are as follows:

1	Immune		
2	Almost immune		
3	Very highly resistant	o	No sporulation
4	Highly resistant	+	Very sparse sporulation
5	Resistant	++	Sparse sporulation
6	Moderately resistant	+++	Moderate sporulation
7	Moderately susceptible	++++	Heavy sporulation
8	Susceptible		
9	Highly susceptible		
10	Very highly susceptible		

This classification is liable to be complicated by the variability in disease severity at different places. Variability due to different climates (as between Turrialba and Belterra) can be assessed, because climatic differences are relatively stable. That due to different strains of the parasite will always be a problem, as strains may spread from one area to another, or may arise anew. In the earlier tests differences between Turrialba and Belterra could be explained by the much greater severity of the disease under Turrialba conditions. Later, differences were found between the ratings of the same clones at Belterra and at Belem, plants usually suffering more from disease at Belterra. It is now accepted that there are different strains of the fungus at these two places (LANGFORD, 1953). Apart from Turrialba and Belterra regional test plots were established at Port of Spain, Trinidad; at Belem, Brazil; and at Tingo Maria, Yurac, and Iquitos in Peru (LANGFORD & TOWNSEND 1954).

The development of resistant material is dealt with under 'Control Measures undertaken in the Americas' on page 311. As the material from the Tapajos River has proved highly susceptible, breeders have had to work with collections of *Hevea brasiliensis* from other sources, and have had to consider other wild species of *Hevea*. The four common species *H.brasiliensis* Muell. Arg., *H.benthamiana* Muell. Arg., *H.guianensis* Muell. Arg. and *H.spruceana* (Benth.) Muell. Arg. all have resistant races, and (except for *H.spruceana*) latex with no notably defective or objectionable properties. *Hevea brasiliensis* var *subconcolor* from the Colombian Amazon has a population with 90% resistant individuals. The more localised species of the 'endemic complex' including *H.pauciflora* (Spruce ex Benth.) Muell. Arg., *H.pauciflora* var *coriacea* (*H.confusa* Hemsley), *H.rigidifolia* (Spruce ex Benth.) Muell. Arg., *H.microphylla* Ule (*H.minor* Huber), *H.nitida* Muell. Arg. (*H.viridis* Huber), and *H.minor* Hemsley are all believed to have a high degree of resistance but very poor latex.

ENVIRONMENT

RAINFALL—The most favourable conditions for disease development are attained when there is abundant rain distributed over a long period so that the foliage is wet for an average of more than twelve hours a day. Long dry periods lead to a reduction in disease.

TEMPERATURE—As the temperature range which favours disease is the same as that which favours growth of the rubber tree this factor in the climate can be discounted.

AIR MOVEMENT—Wind and air currents are important agents in disseminating the disease, as well as affecting accumulation of mists and dew. Exposed east coast areas in British Guiana and Trinidad were far less severely infected than inland areas out of reach of the trade winds which blow for about ten-eleven months of a year.

MISTS AND DEW—The formation of mists and dew, of the utmost importance, is dependent upon the interaction of temperature, rainfall, humidity, and air movement.

HUMIDITY—The intimate coating of moisture provided by a dew deposit is ideal for infection, and heavy infections can take place during an eight hour period of dew. Experience in British Guiana (BELGRAVE 1921) had not confirmed Stahel's statement that the disease is worse in dry weather because of heavier deposition of dew.

SOIL—No evidence of different susceptibility on different soils has been adduced, but the principle applies that continued defoliation will destroy trees more rapidly on a poor soil than on a rich soil. A reduced intensity on coastal soils is related to weather and not to soil composition.

Alternative hosts. No alternative hosts to *Hevea* species have been found. Wild *Hevea brasiliensis* plays the part of an alternative host in areas to which it is indigenous, and other susceptible species of *Hevea* may do the same. In the Guianas *H.guianensis* and *H.confusa* (=*H.pauciflora* var *coriacea*) were a constant source of infection to the planted trees.

Parasites. A species of *Botrytis* is known to parasitise *Dothidella ulei*.

CONTROL

Control is dealt with fully in Section V 'Control Measures Undertaken in the Americas'.

III ESTABLISHMENT OF THE AMERICAN PLANTATIONS

Three phases may be recognised in the establishment of the American plantations. At the beginning of the century, when news came of the satisfactory profits being made in the east, there was haphazard planting in all tropical American territories. Faced with the failure of the majority of these plantations, and the British introduction of restriction in 1922 (WHALEY 1946), the United States government organised a number of surveys designed to explore the prospects for establishment of a full scale plantation industry. These resulted in five important publications. W.L. Schurz, O.D. Hargis, C.F. Marbut, C.B. Manifold on 'Rubber Production in the Amazon Valley' (1925). J.C. Treadwell, C. Reed Hill, and H.H. Bennett reported on 'Possibilities for Para Rubber Production in Northern Tropical America' (1926) both on behalf of the United States Department of Commerce. Carl D. La Rue led an expedition to the Amazon Valley for the United States Department of Agriculture which resulted in his report 'The Hevea Rubber Tree in the Amazon Valley' (1926) and that of J.R. Weir on 'A Pathological Survey of the Para Rubber Tree in the Amazon Valley' (1926). At the same time, also for the U.S. Department of Agriculture, R.D. Rands visited Trinidad and the Guianas, reporting on his visit in 'South American Leaf Disease of Para Rubber' (1924).

The comprehensive survey of the Department of Commerce located regions with suitable climate and soils and selected areas

with adequate population and means of transport. The existence of a sufficiently high level of agricultural population to provide labour naturally goes together with transport in the form of river, roads, or railways. Plant disease was considered briefly as a limiting factor but the authors of this report followed RANDS (1924 page 15) in concluding that the danger of spread of *Dothidella* to new plantations was not great provided that planting material imported from infected areas was restricted to seed, stumps, and budwood. The three big plantations established following this report—Ford's Fordlandia in Brazil, Goodyear's Speedway Estate in Costa Rica, Goodyear's All Weather Estate in Panama,—proved to be expensive and not very productive enterprises largely owing to South American leaf blight, but they provided invaluable knowledge and material for the third phase. This opened in 1940 with the launching of the Cooperative Inter-American Plantation Rubber Development Project (ANON 1940) (RANDS 1942a, b, c, 1945, 1946) (BLANDIN 1941) (BRANDES 1941, 1943a, b, 1945), (BRANDES *et alii* 1946) and (BRANDES 1947), when a comprehensive survey was made in which South American leaf blight was accorded the degree of importance which the experience of the preceding twenty years had shown it merited. Labour and transport became somewhat subsidiary factors because of the high prices emergency measures called forth.

The history of hevea planting in the twentythree countries which comprise tropical America is given below by territories in alphabetical order.

BOLIVIA

H. brasiliensis is indigenous in North Bolivia, but so far as can be ascertained no attempt has been made to plant rubber there. The Acre territory was visited by the U.S. Department of Agriculture expedition led by La Rue in 1923, and a few trees planted at Cobija were seen to be well grown. Advantage was taken of the lack of an embargo on export of *Hevea* to collect several hundred seedlings and seed for the gardens at Pedro Miguel in the Panama Canal Zone.

In 1953 and 1954 interest was aroused in planting rubber and a small nursery was established near Riberalta to furnish high yielding budded stumps and disease resistant top budding clones to interested planters (POLHAMUS 1955).

BRAZIL

Hevea brasiliensis is indigenous over the whole of the Amazon basin, and had been tapped by the Indians long before the discovery of the New World. The growing demand for rubber at the end of the 19th century did not stimulate planting of hevea but it did lead to the collection becoming less haphazard, definite 'tapping tasks' (estradas) of 100-200 trees being laid out and grouped into a seringal. A description of the seringueiro's work is given in the R.R.I. PLANTERS' BULLETIN (1941). By 1910 a few very small plantations had appeared but LA RUE (1926) was not able to find a single plantation comparable with those in the

Orient. The report of this expedition was favourable and in 1927 the Ford Motor Company started Fordlandia, a plantation fully on the oriental scale, 26 miles south of Santarem on the Tapajos River (JOHNSTON 1941a, b). It was from Boim, 40 miles further up the Tapajos, that the first seed to reach the east had been collected by Wickham. By 1930 3,000 acres had been planted and 8,300 by 1934, but that year the plantation was deemed to have failed and the project was transferred to Belterra. Starting in 1934, planting there was well ahead of Fordlandia by 1939, reaching 12,230 acres. A proportion of top budded trees were established, clones being obtained from trees which survived the leaf blight at Fordlandia.

Early in 1934 a consignment of 2,046 stumped buddings from 53 of the best eastern clones arrived from Malaya and Sumatra. Of these 1,201 survived and were planted at Fordlandia. In 1937 this material was used for large scale budding on Belterra. Various small plantations were established elsewhere in Brazil, notably at Bahia and Ilheos.

A major contribution of Brazil to the rubber project were the facilities granted to the U.S.D.A. Cooperative Field Laboratory at the Instituto Agronomico do Norte in Belem (MALLERY 1941), which became a local disease study centre and had multiplication gardens for the Ford resistant clones. These clones were selected from seedlings from both Belem and the Upper Amazon, and budwood from jungle trees in the Acre Territory and Rio Negro area (LANGFORD and TOWNSEND, 1954).

The Brazilian government is continuing to encourage rubber production within its territories, especially as Brazil is now a rubber importing country (GERRITSEN, 1954) (BEKKEDAHL 1945).

BRITISH GUIANA

The history of the rubber planting industry in British Guiana is confined to the first phase referred to above, as it had practically ceased by the time of the Department of Commerce expedition in 1923. There was certainly no extension during the middle period, as the knowledge of previous disasters and the over-production in other British territories ruled it out. The territory did not participate in the 1940 rubber project.

An early start was made with direct imports from Kew in 1895, and from Trinidad 1896-99. From 1900 onwards there were shipments of seed from Singapore practically every year. In addition, private introductions were made from Ceylon, Trinidad, and Surinam. Experiment stations were established at the Georgetown Botanic Gardens at the mouth of the Demerara River, at Onderneeming on the Essequibo, at Issororo on the Aruka, and in the Pomeroon district at Christianberg. A number of small commercial plantings were made at points along the main rivers, several of them experimentally on sugar plantations. Larger areas were planted in the Northwestern district. Altogether there were 5,200 acres under rubber in 1917. By 1921 the acreage had dropped to 2,813 and production to a mere 1,568 lb—soon to cease altogether.

BRITISH HONDURAS

As might be expected, from there being so much rubber in other British territories, no plantations were built up in British Honduras. In the initial boom period a few experimental plantings were made, presumably all with seed imported from Singapore about 1900. In 1910 some of these trees were growing well in the Belize botanic gardens.

COLOMBIA

Hevea brasiliensis is indigenous over the whole of the interior of Colombia, which extends as far as Leticia on the upper Amazon. No record has been found of rubber having been planted until the cooperative rubber project commenced in 1941. The 1940 survey had named a number of suitable areas, of which the best were along a sixty mile stretch of the Inter-American Highway inland from Turbo on the Gulf of Uraba (SORENSEN 1945), and in the region of Acandi on the Gulf of Uraba a few miles south of the Panamanian frontier. The first nursery was started at Acandi in February 1941 with budded stumps from Tela, Honduras. Nurseries were also established at Turbo itself and at Apartado, with seed from Belem (via New York), seed from the Canal zone, and budded stumps from Honduras (HARGIS *et alii* 1946). In 1942 an additional nursery was started at Riogrande, a few miles north of Apartado to which it was planned to remove the Apartado material. A headquarters with nurseries and experimental plots was established at Villa Arteaga near the Sucio River. Budwood and budded stumps were introduced from Honduras and seed from Costa Rica. In 1943 more seed was introduced from Costa Rica, and also seed from Leticia on the Colombian Amazon. By 1944 sufficient material had been accumulated to allow commercial planting to commence in the Uraba for Villa Arteaga was the only nursery kept up. A Colombian Government corporation to foster rubber planting was in existence in 1945, similar to that established by the Peruvian Government and every encouragement given to smallholders (SCHULTES, and ALFONSO URIBE 1947).

COSTA RICA

A small plantation of trees was established in the Turrialba Valley about 1914 and made excellent growth on the rich soil there. The lower land north of Turrialba, the San Juan plain, was favourably reported on by the Bureau of Commerce Survey (TREADWELL *et alii* 1926) for its climate and excellent soils. The United Fruit Company chose Cairo, in the southern part of this plain on the Reventazon River, as the site for one of their plantations. Here in 1926 Louisiana Farm was planted with 300 acres of hevea with seed from Malaya. Louisiana was subsequently abandoned until the property was taken over by the Goodyear Company in 1936 with the late W.N. Bangham as manager. Bangham used seed from the existing ten year old trees (which, incidentally, he found infected with leaf blight) to establish nurseries for stocks on which far east clones were

budded and then resistant clones top-budded. By 1938 1,000 acres of three component trees had been established, and in 1941-43 a further 1,500 acres of Ford and far east clones were planted on the neighbouring farm of La Francia. The total 2,500 acres constitutes Goodyear's Speedway Estate (ALTSON 1951).

When the leaders of the Rubber Investigation Project came to select a site for a central experiment station for work with *Dothidella*, Turrialba was chosen (GRANT 1946). It is situated about twenty miles up the railway from Cairo, and forty miles down from San Jose, at an altitude of 2,000 feet. A site for experiments under more normal conditions of disease incidence than those prevailing at Turrialba was found at the Los Diamantes farm at Guapiles, ten miles up the branch line from its junction with the main line at Cairo. Los Diamantes is situated on good soil of the San Juan plain at an altitude of 800 feet. In 1950 there were about 375 acres of hevea at Los Diamantes and 75 acres at La Hulera, Turrialba (ALTSON 1951).

CUBA

A small number of *Hevea brasiliensis* trees were planted in Cuba for experimental purposes about 1908 (TREADWELL *et alii* 1926). Some were planted at Santiago de Las Vegas, the Government Experiment Station south of Havana; some at the Atkins Institution of the Arnold Arboretum tropical plant introduction gardens at Central Soledad, near Cienfuegos; others elsewhere on the island. These experimental plantings demonstrated that the climate of Cuba is not suitable for commercial rubber plantations. Cuba however became a valuable member country of the cooperative rubber project because of the quarantine facilities at Soledad.

DOMINICAN REPUBLIC

In the early 1920's the Goodrich Rubber Company sent a survey party to collect selected seed from Brazil for planting in the Dominican Republic. Under the rubber project nurseries and plantings were established at Piedras Blancas, where the Goodrich seedlings were finally located.

DUTCH GUIANA

Hevea brasiliensis has been cultivated and studied by the Surinam Department of Agriculture at its plantations at Slootwyk and at the Paramaribo Gardens from the beginning of the century to the present day. Material supplied by other American territories was tested for susceptibility in Surinam, but no Memorandum of Understanding was signed (HONIG *et alii* 1947). Commercial planting was stimulated by the high rubber prices of 1910-12 but by 1920 rubber cultivation was being dropped completely in favour of cacao, coffee, sugar and bananas.

ECUADOR

Despite the failure of *Castilloa* rubber after big efforts to establish it, and despite the fact that *Hevea brasiliensis* is indigenous in eastern Ecuador, the only planted hevea in Ecuador in 1923 consisted of some 550 trees at Tenguel, near Balao.

Ecuador's cooperative agricultural experiment station was sited just south of the equator between the Rios Quevedo and Macul, 100 miles N.N.E. of Guayaquil (LONG 1944). The station was started during 1943 when rubber nurseries were established with seed imported from Honduras.

EL SALVADOR

No hevea rubber was located by the Department of Commerce Expedition, which reported parts of coastal Salvador as suitable rubber growing areas provided that moisture retaining soils were chosen.

A U.S.D.A. cooperative experimental plantings was started in El Salvador in 1941 at San Andres and its rubber nurseries built up with material from Honduras imported during 1942-44. There was little interest in rubber planting and the work was not followed up (POLHAMUS 1955).

FRENCH GUIANA

Rubber has never played any part in the economy of French Guiana, although the collection of wild balata has been second only to gold mining in importance.

GUATEMALA

Guatemala escaped the initial phase of planting (see page 297) altogether so far as hevea was concerned. A few plants survived in 1940 at Cubilguitz (27 miles north of Coban in central Guatemala) of trees from seed introduced via Curacao in 1929. The west coast region of Guatemala appeared very promising to the investigators in 1940. They at once started several nurseries which were ready for budding with oriental clones when budwood of these arrived from Honduras in 1941. At the same time 300,000 seeds from Honduras were distributed, a proportion being used to start a multiplication garden at Hacienda Trapiche Grande, Cuyotenango, which became the cooperative centre (LA RUE *et alii* 1946b). More budded stumps came from Honduras in 1942, and seed from Mexico and Liberia. By 1944 *Dothidella* resistant material was available, Ford clones having been introduced from Florida and a large shipment of others from Nicaragua. More seed was brought in from Honduras. In 1945 disease resistant selections were growing well and the first round of top budding was carried out on non-resistant clones. Experiments were laid down to determine the effect of top budding on yield in field plantings totalling 1,600 acres.

HAITI

Rubber planting in Haiti commenced in 1903 with the planting of a few hundred trees by a private farmer at Bayeux, on the north coast; these were abandoned in 1912. Even before the Department of Commerce survey reported Haiti as a suitable country for smallholders' rubber production the U.S. Department of Agriculture resuscitated the Bayeux plantation and started tapping experiments there on the original trees. At the

same time the department planted about twenty acres a few miles east of Port au Prince with Bayeux seed. Having these areas of disease free mature rubber trees of known growth and yield, Haiti came to play an important part in the expansion of the western hemisphere rubber industry with the start of the rubber project in 1940 (FENNELL 1941). In March 1941 the 400 acre Marfranc Central Rubber Nursery was established (with seed from Bayeux) five miles up the Grand Anse river from Jeremie, on the southern peninsula. In April a shipment of 4,800 budded stumps from the Philippines arrived at Marfranc to become one of the multiplication gardens for far eastern material along with those in Mexico and Honduras (POLHAMUS 1942). In August the Société Haitiano-Americaine de Dévéloppement Agricole was formed and started work on two large rubber plantations (ANON 1942). The larger was in the Grand Anse valley and the smaller in the Bayeux valley. By 1946 a total of 6,500 acres had been planted. In 1950 Haiti was the only remaining territory in America where a fair acreage of rubber could be grown under suitable climatic conditions yet free from leaf blight, consequently it was here that one of the three regional rubber experiment stations was sited in 1950.

HONDURAS

Early ventures in rubber planting were confined to *Castilloa* and proved failures. Banana production has always dominated the country's agriculture. The United Fruit Company maintained an introduction garden at Lancetilla, a few miles south of Tela (STANWOOD 1944). In 1926-27 two small plantings of hevea were made here, the first of 500 trees with seed from Costa Rica, the second of 474 trees with selected seed obtained from the United States Rubber Company in Sumatra. When the rubber project commenced, in 1941, seeds from these trees were used to establish the first U.S.D.A. Rubber Plant Field Station nurseries. Early in 1941 four thousand budded stumps of far eastern clones were obtained from the Philippines (POLHAMUS 1942) and planted at Lancetilla, which became an important multiplication garden and distribution centre.

Small commercial plantings were made in Honduras, of which the largest in 1944 was that of the United Fruit Company at San Alejo. The Standard Fruit Company for some years previously had kept a small plantation at La Ceiba.

JAMAICA

The first rubber trees were planted in the gardens at Castleton and Hope in 1894. Ten years later Fawcett, writing in the first number of the Botanical Department Bulletin, reported that tapping had not commenced, and after a further twenty five years the planting was declared a failure.

MEXICO

There are conditions suitable for the cultivation of hevea in the South of Vera Cruz State and along the inland border of the Gulf State of Tabasco and the Pacific State of Chiapas

as far as the Guatemalan frontier. The first plantings were made by J.C. Harvey at the Hacienda El Palmar 24 miles south east of Cordoba, Vera Cruz. Of twenty seed which were sent from Singapore on 12 February 1903, and arrived on 3 May of that year, fourteen grew.

Between 1908 and 1911 stumps and seed were imported from Ceylon to start several plantations, which were later abandoned, in the Chiapas/Tabasco region. The largest was at Las Palmas. One of these plantations, on the Chumula River, was planted in 1910 with seedling stumps the origin of which is not now known.

No sizeable plantings appear to have been made until 1941 when the U.S.D.A. survey reported Mexico free from *Dothidella*, and El Palmar a suitable site for a multiplication nursery. Budded stumps were imported from the Philippines in March of that year (POLHAMUS 1942). Fifty pounds of seed from Dothidella resistant trees in Brazil were planted but failed and nurseries were therefore built up with local seed (LA RUE *et alii* 1946a). At the end of 1941 budded stumps from Honduras were introduced. The next year plantings were extended with selected clones from Honduras and clonal seed from Liberia, and the year after, with budwood brought in by air from Honduras. By 1950 a number of communal farms had been organised in the El Palmar region, and in the Tabasco-Chiapas area private owners were combining rubber production with mixed farming (FOREIGN RELATIONS OFFICE 1950).

NICARAGUA

In 1901 planting of hevea commenced with one of the earliest introductions of seed from the east into the western hemisphere. The seed was planted in a castilla plantation at Cukra, near Pearl Lagoon, twenty miles up the Escondido River from Bluefields, the main port of eastern Nicaragua. The whole plantation was almost totally destroyed by a hurricane in 1906, and not replaced. The abandoned area was visited by the Department of Commerce expedition in 1923 and seed collected from a few well grown surviving trees. The expedition reported favourably on eastern Nicaragua as a site for hevea cultivation, but this development came only with the Rubber Project in 1941 (MONCURE 1946). El Recreo, sixty five miles up the Escondido from Bluefields, was chosen as the site for the cooperative Agricultural Experiment Station, with a sub-station at Cukra Hill. At these places 500,000 rubber seedlings were established and budded with high yielding far east clones, budded stumps subsequently being distributed to cooperating growers.

PANAMA

The Department of Commerce expedition recorded a number of small plantings of hevea in the Republic of Panama. In the Canal Zone a collection of *Hevea brasiliensis* plants from Trinidad, the Amazon, Costa Rica, Bolivia and Nicaragua had already been started in 1923 at the Summit Gardens, Pedro Miguel. The

expedition particularly recommended the Canal Zone as a site for a plantation in view of its being the only United States territory in the American continent climatically suitable for hevea, and because of the ease of communication with both markets and with any other territory that might require planting material. In 1935 the Goodyear Rubber Company selected a site at Gatun Lake and planted up All Weather Estate (ALTSON 1951) which was abandoned in 1941, having been devastated by leaf blight. All Weather Estate was in 1943 transferred to the Institute of Inter American Agricultural Sciences and has been at least partially maintained since.

With the start of the Rubber Project in 1941 some use was made of the Summit Gardens for breeding work (ALTSON 1951). The gardens were not suitable as a site for multiplying far eastern material owing to the presence of *Dothidella*.

The Republic of Panama was one of the countries cooperating in the Rubber Project. A small experimental planting of seven far east panel clones top budded with nine resistant clones was made from three component trees in 1947 and maintained at the National College of Agriculture farm at Divisa.

PERU

Until the year 1918 Peru supported a thriving rubber industry with its indigenous rubber (SANCHEZ DEL AGUILA 1941) (SEIBERT 1947). The wild rubber industry recommenced in 1941 and at the same time a plantation rubber industry started with the planting of nurseries at Tingo Maria and Oromina. Upon the cooperation agreement being signed between Peru and the United States Tingo Maria became the site of the main agricultural experiment station for the lowlands east of the Peruvian Andes (MOORE 1943). A main highway runs 400 miles from Lima to Tingo Maria, at a height of 2,200 feet on the eastern slopes of the Andes and on the Huallaga River. In another 100 miles the highway ends at Pucalpa on the Ucayali River. Along the highway from Quebrada Caracol to Pucalpa small plantations have been established, as well as at places down the Huallaga and Ucayali and along the Upper Amazon (into which both rivers flow) as far as Iquitos. Tingo Maria provided the centre for introduction and propagation of *Dothidella* resistant clones from Costa Rica, Honduras, Haiti, and Belem. By 1950 a corporation for encouraging rubber growing, the Corporacion Peruana del Amazona, had been formed similar to that in Colombia. This was responsible for larger plantations at Yurac, Yurimaguas, and Fondo Iberia in the Madre de Dios region (MARASSI 1951).

PORTO RICO

Hevea rubber trees were introduced by the Department of Agriculture for experimental purposes in 1923, although no commercial possibilities were foreseen. The U.S. Department of Agriculture has a Federal Experiment Station at Mayaguez, where breeding gardens were established (WHITE *et alii* 1945).

TRINIDAD

A detailed account of the Trinidad rubber industry up to

1917 has been published (LAMONT *et alii* 1917). The first introduction of *H.brasiliensis* consisted of two plants from Kew in 1876. Later, seed was imported from Ceylon and Singapore, while some plants at St Augustine came from the Rio Negro. In 1916 thirty five estates reported hevea on their properties, mostly grown in conjunction with other crops. The largest planting was on Non Pareil, situated on the eastern coast, and by 1923 it was virtually the only estate still in production.

VENEZUELA

A certain amount of rubber of *Hevea* species is indigenous in Venezuela and has been tapped in the forests. *Hevea brasiliensis* material was imported from Honduras during the period 1942-44, some being planted at Caripito on the north east coast only 100 miles from Trinidad. Venezuela was not a cooperating country in the Rubber Project (FOREIGN RELATIONS OFFICE 1950).

IV THE COURSE OF THE DISEASE IN THE AMERICAN PLANTATIONS

It may be asked why an indigenous disease, which never seems to have interfered with the production of wild rubber from the Amazon basin, should be so feared when trees are grouped together to form plantations. A consideration of the history of the disease in the American plantations leaves no doubt as to the severity of the attack, and indicates the factors which lead to it. The classic example is the destruction of the plantation rubber industry in British Guiana, which has been well documented and is given in some detail here.

It has been suggested that the sparse wild population of *Hevea* represented the resistant survivors from a much larger original population. Against this many of the present plantations which succumbed to the disease were made with seed from these trees. It is clear that the 'immunity' of many of the jungle trees is due to the fact that being isolated from their neighbours they have never been exposed to a high concentration of infective material.

TRINIDAD

J.B. Rorer, in an appendix to the Report on Rubber Cultivation in Trinidad (LAMONT *et alii* 1917), first identified leaf blight in Trinidad in July 1916. He concluded that it had been present in Trinidad for a number of years, but had only recently become epidemic. The disease was more widespread in 1917 and occurred in several different districts. In some the trees were scarcely affected, in others trees had been killed by repeated defoliation. Rorer estimated the disease to be less serious in Trinidad than in the Guianas. Certainly less hevea had been planted in Trinidad, and the largest plantations happened to be on the east coast where leaf blight is much reduced by prevailing climatic conditions (ALTSON 1924).

W.N.C. Belgrave visited Trinidad in November 1920 (BELGRAVE 1921) and described a severe attack in a well tended nursery of 5-7 months old seedlings. He did not observe any leaf blight on badly grown old rubber nearby.

In 1923 R.D. Rands found that although plantations in the south were badly infected those in the north and east, and individual trees in exposed situations, escaped severe infection. The next year ALTSON (1924) observed the mildness of the attack on mature trees in most parts of the island, despite a general infection of seedlings.

DUTCH GUIANA

BANCROFT visited Surinam late in 1916 and reported (1917) the disease to be rampant and much more serious than in British Guiana (see below) despite the similar climate. The total area under cultivation, mostly interplanted, was 2,400 acres. The disease was sporadic and did not become epidemic until 1914 (STAHEL 1915), by 1916 trees of all ages were dying from repeated defoliation. Destruction of wild *Hevea* had proved expensive and fruitless, and spraying ineffective (STAHEL 1916). Suggestions for simultaneous defoliation of large areas by 'smoking' or 'gassing' were made.

Stahel reported on the fate of the Lawa Caoutchouc Compagnie (STAHEL 1919) and the following is a summary of his description by R.D. RANDS (1924):

> From 1911 to 1915 a mining company at Lawa, on the upper Marowyne River, put out 40,000 trees of **Hevea brasiliensis**. Since the trees were grown from imported seeds and stumps and the estate was located some 200 kilometers distant from the nearest Para rubber planting, the chances of the disease being introduced were very slight. Although the estate was reported to be in a very healthy condition as late as 1917, collections of leaves received at Paramaribo showed the presence of the disease. According to the manager of the estate, nothing abnormal occurred until March, 1918, when as a result of heavy fog frequently covering several hilltops planted with rubber, the disease appeared in epidemic form and spread to the rest of the planting. In six months, time, as a result of repeated loss of the young leaves, one-third of all the trees died, and the remainder showed a hopeless condition. This very promising estate was therefore completely ruined in a half year's time and was subsequently deserted.

Rands himself visited Surinam in 1923 (RANDS 1924) and confirmed Bancroft's impression that the disease was even more serious than in British Guiana. He suggested that this was due to the Surinam plantations being further inland than those of British Guiana and therefore away from coastal winds. In addition the Surinam plantations were closer to indigenous and naturally infected *Hevea guianensis*. Rubber had occupied about 3,000 acres mostly interplanted with coffee, but was gradually being cut out for more profitable crops. Rands gathered from Stahel and from others concerned in rubber production that high labour costs coupled with disease had rendered hevea no longer worth growing and the industry was being abandoned (STAHEL 1927).

BRITISH GUIANA

A disease showing the symptoms of leaf blight appeared

in British Guiana in 1909 on trees from Singapore seed. It appeared again in 1911, and in 1913 was collected (BANCROFT 1913). The Governor found it necessary to issue a reassurance concerning the disease (EGERTON 1915). By 1916 the disease had spread everywhere except to the Essequibo Coast and the greater part of the Demerara Coast. There was no record of it on some 50,000 seedlings at Georgetown Gardens. Isolated plantations of six year old trees 50 miles from any other planted *Hevea* had been attacked (BANCROFT 1916). Extensive areas had to be abandoned (FRANCIS 1923) including the Experiment Stations at Christianburg and Issororo (BODKIN 1922). Belgrave visited British Guiana during a prolonged dry spell and although he saw abundant leaves with lesions none had been recently attacked (BELGRAVE 1921).

In July 1923 R.D. Rands, accompanied by R.A. Altson who had but a few months previously taken up the post of botanist and mycologist in British Guiana, visited the 1910-11 plantings on the Lower Essequibo river which had been attacked by leaf blight about 1918 and subsequently abandoned. He described them as follows (RANDS 1924):

> One very dense planting about 12 years of age seemed to have suffered little until the last year or two, since the trunks were of normal size. At the time of examination, however, some of the trees showed numerous dead branches, and scarcely a half grown leaf could be found which was not distorted or badly spotted, indicating a belated infection. Other trees with mostly mature leaves would have been considered as yet unattacked had there not been occasional dead branch tips indicating repeated defoliations last year.
>
> In a younger planting, 4 to 6 years of age, less than a quarter of a mile distant from the above, the disease was seen in its most active stage during an epidemic which had apparently been in progress for two weeks. Fully half the trees had just passed the 'wintering' period and were developing new leaves, which averaged from a few days to a week or more in age. As pointed out by earlier writers, this period is less defined in the South American countries than in the Far East. In the Guianas it is said to require three to four months' time before all the trees in a planting have lost their old leaves and grown new ones. Large variations also occur between different branches on the same tree in the time of dropping their old leaves.
>
> As noted on July 24, the foliage of this younger planting was everywhere discoloured, twisted, or crumpled, and falling off. In most cases the leaflets had dropped in advance of the long, slender petioles, giving the ends of the branches a peculiar bristly appearance. On other trees the naked succulent branch tips themselves were discolored, and stem swellings farther back indicated still earlier infections. A number of trees had died the year before and the amount of die back, although less evident on account of the defoliated condition of the trees, was nevertheless outstanding enough to show that the planting had suffered seriously in the past. A more ruinous condition could scarcely be imagined. The disastrous effect on the flow of latex from the repeated defoliations in combination with relatively high labor prices had naturally made further tapping unprofitable, a situation which is said to exist practically throughout the colony.

Altson (1925, 1926) reported the abandonment of most of the inland plantations, but the comparative freedom from infection of those on the coast.

EXTENSION OF PLANTATIONS FOLLOWED BY EXTENSION OF THE DISEASE

It is not always easy to sort out how far leaf blight and how far other causes were responsible for the abandonment of all or part of the plantation projects which started up after the publication of the U.S. Department of Commerce's report in 1926. On Fordlandia, started in 1927, further clearing was stopped in 1933 and another site sought (JOHNSTON 1941a, b). The next year 1,732 acres of the 8,300 acres planted were condemned for rubber cultivation and the undertaking transferred to Belterra. There a certain amount of top budding was carried out, as eventually became the usual policy.

The efforts of the Goodyear Rubber Company in the Panama Canal Zone in 1935 fared no better. No top budding was carried out, as at that time Panama was well outside the known range of the disease. Yet All Weather Estate was devastated by leaf blight from 1938-1941 and then abandoned. The Canal Zone gardens remained free from the disease until 1939 (ANON 1941). Profiting by the knowledge that leaf blight was in Central America (STEVENSON 1935) and realising the damage it could do, in the Goodyear plantation of the next year (1936) some 2,500 acres were top budded under the supervision of W.N. Bangham. This was at Cairo in Costa Rica and was yielding 350 kg per hectare in 1950 (TOLLENAAR 1954a). The United Fruit Company's 1926-27 plantation at Lancetilla, Honduras, was the only one with susceptible material to succeed.

COOPERATIVE RUBBER PROJECT PLANTATIONS IN THE COUNTRIES WITH INDIGENOUS LEAF BLIGHT

With the failure of Fordlandia as an example of what could happen no attempt was made to plant non-resistant material in countries with indigenous disease, however far from known outbreaks. In Brazil the Cooperative Field Laboratory at the Instituto Agronomico do Norte was made a centre for the distribution of Fordlandia resistant clones. In 1950 it was one of the three local disease study centres (the other two being the Campo Experimental de Hule at El Palmar in Mexico, and an experiment station at Tingo Maria in Peru).

There was some cooperation with workers in Trinidad and the Guianas during the war years. An Inter-Governmental Memorandum of Understanding was agreed with Trinidad and a regional test plot of clones of varying susceptibility established there (LANGFORD 1946). A similar plot was established in Surinam although no Memorandum of Understanding was signed. These plots were designed to determine whether or not there were local strains of *Dothidella*.

In Venezuela, the disease appeared in 1942 at the Caripito nurseries only 100 miles from Trinidad (LASSER & RODRIGUEZ LANDAETA 1944).

In Northern Colombia, lying as it did between indigenous disease in the south and infected Costa Rica and Panama in the

north, care was taken to organise top budded plantations from the start. Leaf blight gave considerable trouble in the nurseries where high yielding material was growing prior to top budding, appearing at Riogrande in 1943, on seedlings from Costa Rican seed. A second consignment of Costa Rican seed was given hot water treatment at Turbo before forwarding on the suspicion that the disease was seed borne (HARGIS *et alii* 1946). At Villa Arteaga in 1942 there were 78 per cent failures in the budding programme due to leaf blight.

The position in Peru is comparable with that in Colombia. Both countries have rubber areas communicating either with the coast along a central highway, or in the interior with the upper Amazon by means of its tributaries. Both countries have formed rubber planting corporations to encourage the mixed crop smallholding type of rubber production. Less information is available on the disease in Peru, but Iquitos, on the Peruvian Amazon, was one of the first localities from which it was collected. Rubber project nurseries sited at Iquitos required weekly spraying, and LORENZ (1948) mentions *Dothidella* resistant material being used throughout the rubber growing areas. Its establishment was being hindered by Target Spot caused by *Pellicularia filamentosa*.

Ecuador, sandwiched between Peru and Colombia, has indigenous leaf blight in the interior but no information is available as to whether the Hacienda Pichilingue plantings have become infected.

COOPERATIVE RUBBER PROJECT PLANTATIONS OUTSIDE THE NATURAL RANGE OF S. A. L. B.

TABASCO-CHIAPAS REGION OF MEXICO—It is considered (MARTIN 1948) that the planting on the Chumula River must have been made with infected material brought in as seedling stumps in 1910, as it was heavily infected in 1946 had obviously been so for many years, and no other introductions were known. Volunteer seedlings had been removed from this planting and sold to other planters in the area, and it is most likely that these plants were the origin of the outbreak at Las Palmas which must have occurred about 1944, and the infection of the Teapa nurseries reported in October 1946 (MARTIN 1947).

VERA CRUZ REGION OF MEXICO—Once the Teapa-Tabasco area was infected the disease rapidly spread, presumably by migration of workers, to the Campo Experimental do Hule at El Palmar (MARTIN 1948). By 1950 this station had become one of the three local centres in the Americas for special study of leaf blight.

HONDURAS AND NEIGHBOURING TERRITORIES—The freedom from disease of the United and Standard Fruit Companies' plantations commended Honduras as a centre for the distribution of susceptible high yielding material to Guatemala, El Salvador, and Nicaragua, as well as to countries further afield. Later it became a distributing centre for resistant material and by the

time leaf blight reached these countries (after November 1946) top budding clones were available to counter it. The trees at Cubilguitz, Guatemala, had been specially noted as free from leaf blight in 1940. No record has been found of the disease appearing in British Honduras, though the disease is stated to have completed its spread into every rubber growing territory on the American mainland by appearing in Honduras itself in 1952 (WAITE and DUNLAP 1952).

THE CARRIBEAN ISLANDS—Haiti, the Dominican Republic, Porto Rico, Jamaica and Cuba remain free from South American leaf blight.

V CONTROL MEASURES UNDERTAKEN IN THE AMERICAS

If the severity of South American leaf blight had been appreciated fifty years ago steps to control it would have taken the form of quarantine and plans for eradication in those territories to which it was not indigenous, and spraying to protect young plants together with breeding of resistant material in the indigenous areas. Once resistant material became available it would have been desirable to import some into the healthy territories lest their quarantine precautions and plans for eradication were to fail. This is the position now in tropical America, although the areas free from disease, and so able to be protected by quarantine laws, are represented now by only the Carribean Islands.

QUARANTINE

The history of the establishment of the American plantations shows that at the beginning of the century seed was more readily obtained from the east, where leaf blight was unknown, than from neighbouring countries. Thus fortuitously and without any special laws the very best form of quarantine was practised. In two known cases outside the natural range of *Dothidella ulei* —Trinidad and the Chumula River district of Mexico—seedling stumps were introduced from elsewhere in South America and the disease followed.

The need for quarantine was stressed by the U.S. Department of Agriculture investigators in putting forward their suggestions for further territories suitable for hevea culture (RANDS 1924 page 15). In spite of quarantine the disease appeared in Panama and Costa Rica. Quarantine measures were out of the question at Fordlandia and Belterra, surrounded as they are by indigenous *Hevea.*

ERADICATION

An eradicant campaign was launched in British Guiana in 1915 as a result of Bancroft's recommendations. Legal powers were derived from the Plant Diseases and Pests (Prevention) Ordinance of 25 September 1915 which required infected trees to be sprayed with Bordeaux mixture, dead parts to be burnt,

and the resulting wounds tarred. The measures were, not surprisingly, completely ineffective. STAHEL (1917 page 107) recommended eradication as a method of control. Assuming the ascospores to be non-viable he considered that elimination of the young leaves, on which the conidia are dependent for growth and sporing, would mean elimination of the disease. He advocated pruning off all new shoots appearing over a period of about a month.

SPRAYING

Unlike the spores of some fungi those of *Dothidella ulei* are thin walled and readily killed by fungicidal sprays. KUYPER (1911) proposed using Bordeaux Mixture. BANCROFT (1913) advised boiled lime sulphur prepared from 4 lb sulphur, 2 lb quicklime and 10 gallons of water. BANCROFT (1916) changed his recommendation to Bordeaux Mixture and the same fungicide was recommended by STAHEL (1917). Although these measures were effective with nursery plants they were out of the question with large trees, and held no hope of controlling the disease.

With the coming of the rubber project of 1940, and plans to propagate resistant material on a large scale, methods of spraying nurseries became of major importance (LANGFORD 1944). The work was carried out by M.H. Langford, first at Goodyear's All Weather Estate in the Canal Zone, then in Costa Rica at Goodyear's Speedway Estate and at the Turrialba Co-operative Rubber Plant Field Station. The results of his trials, published as a U.S.D.A. circular (LANGFORD 1943), led him to recommend an 'insoluble' copper fungicide at about 2 lb per hundred gallons, with added spreader and sticker. This could be used safely at weekly intervals to bring seedlings to a buddable size. At Cairo Estate after one year only 18 per cent of the unsprayed plants were buddable, as against 70 per cent of the sprayed. Under the more severe disease conditions of Turrialba over 60 per cent of sprayed plants could be budded after one year but none of the unsprayed. Continuation of the same programme could readily be carried out with knapsack sprayers in a field planting, to bring the high yielding but susceptible panel clones to a stage for top budding with a resistant crown. When spraying high yielding panel clones for multiplication of budwood Langford recommended replacing the copper fungicide by a dispersible sulphur some weeks before the budwood was to be cut, because of the deleterious effect of copper on budding success.

On the basis of preliminary tests at Turrialba Langford recommended ferbam (ferric dimethyldithiocarbamate) in the form of Fermate, as an effective substitute for insoluble copper fungicides should copper be in short supply. Tests with the dithiocarbamate series of fungicides were continued and by 1951 one of them, zineb (zinc ethylenebisdithiocarbamate), was established as superior to insoluble coppers for field use (LANGFORD and ECHEVERRI 1953). Zineb was used as Dithane Z 78 and as Parzate (both 65% zineb with 35% inert filler) at the rate of 1.5 lb per 100 U.S. gallons with 1 quart of rosin emulsion as

sticker and spreader. After one year of spraying every eight days with Dithane Z-78, 90 per cent successful buddings were made at 6 ft compared with 87 per cent success after spraying a copper fungicide every four days. Zineb did not have the retarding effect on growth which resulted from repeated applications of copper fungicides. It has now replaced copper on many of the tropical American stations.

BREEDING RESISTANT MATERIAL

Control of plant disease by breeding resistant varieties has become a most important technique with short term crops such as cereals or cotton. It is a far more formidable task with trees, owing to the time that elapses before the new generation can be tested. When deliberate breeding began in tropical America in 1934, part of the programme had been completed by natural selection among the wild trees in the Amazon Valley and by experimental selection in the far eastern plantations, the benefits of which were brought to Fordlandia in 1934 just before export of high yielding clones was prohibited by the oriental countries. Fordlandia again benefited in 1940 by receipt of clones from the Philippines, a country that had remained outside the International Rubber Regulation agreement. Fortunately there was a short cut that could be used to establish plantations while the breeding to combine yield and resistance went ahead. This consisted of budding a resistant crown on to a high yielding panel clone which in turn had been budded on to a seedling rootstock (SORENSEN 1942), a method that had been proposed for use in Indonesia (MAAS 1934) (DE VRIES 1926) and became standard practice together with spraying (CARPENTER 1951). LANGFORD (1953) pointed out that it is not sufficient to top bud merely with any clone that appears resistant to leaf blight. Clones to be suitable for top budding must neither have too slow nor too rapid growth, they should not be susceptible to *Phytophthora* nor have poor vegetative structure, and they must not have any depressing effect on growth or yield of the panel clone. Langford quoted the following six top budding clones as not yet having shown any outstanding defects at Belterra: F 1619, FB 54, FB 3363, F 212, F 1620 and FB 3333. In practice a plantation is budded with a mixture of resistant crown clones to guard against heavy losses due to the failure of any one of them to resist a new strain of the fungus (LANGFORD & TOWNSEND 1954).

In breeding to combine yield with resistance Langford reported the *H.benthamiana* clone F 4542 as most promising. It has proved resistant to *Phytophthora* leaf fall, as well as to target spot, and 50 per cent of the progeny from certain back crosses to the high yielding parent are resistant to leaf blight. Of *H.brasiliensis* clones F 351 has proved most promising as a resistant parent.

VI ESTABLISHMENT OF THE FAR EASTERN PLANTATIONS

Since leaf blight is found only on certain species of the genus *Hevea*, and this genus is indigenous to the Amazon Basin, it

follows that its accidental introduction into another region is unlikely to occur except in transferring planting material. The territories destined to become the future producers of hevea rubber all received their initial stocks of material at about the same time.

INDIA

The first *Hevea* trees in the east were six seedlings planted in northern India at the Calcutta Botanic Gardens. Cuttings from these trees were distributed to Sikkim. These were from 2,000 seed collected by Farris at Cameta, near Belem, of which a dozen had germinated at Kew after being planted there on the 2 June 1873. Fortunately, for the material was of inferior quality, these trees had died out by 1876.

Later, the plantations in southern India were built up with seed from Ceylon.

CEYLON

Of the 70,000 seeds despatched by Wickham from the Amazon, 2,700 germinated at Kew. Ceylon received 1919 of them on 13 September 1876. Some were planted at Heneratgoda and others at Peradeniya. The trees were seeding by 1890 but other introductions were made after that date. One such introduction was of 300,000 seeds planted at Dehiowita in 1907.

MALAYA

It is recorded that 50 seedlings of the original Wickham collection were sent to Singapore Botanic Gardens but died in transit. The next year (1877) 22 arrived, 11 being sent to Kuala Kangsar in Perak, and 11 planted in the Singapore Gardens where they first seeded five years later.

JAVA

Two Wickham seedlings were received via Singapore and until recently were growing in the grounds of the Central Agricultural Experiment Station at Bogor. In 1882 the first Malayan seed was received. A number of introductions have been made since. P.J.S. Cramer sent several small collections of seed gathered during his visit to Surinam and Brazil from 1912 to 1913.

OTHER FAR EASTERN COUNTRIES

Most of the other far eastern countries must have built up their plantations with seed from Ceylon and Malaya. Even certain American countries were importing seed from Singapore as early as 1894. It is known that Africa was used as a intermediate station for some importations. The important and fortunate fact is that all planting material had to leave South America as seed, and in most cases received unintentional, yet effective quarantine, by being germinated and grown to seedlings at an intermediate place. Had air transport been available to the early importers there is little doubt that leafy planting material would have been transferred, the need for disinfection not realised, and leaf blight introduced.

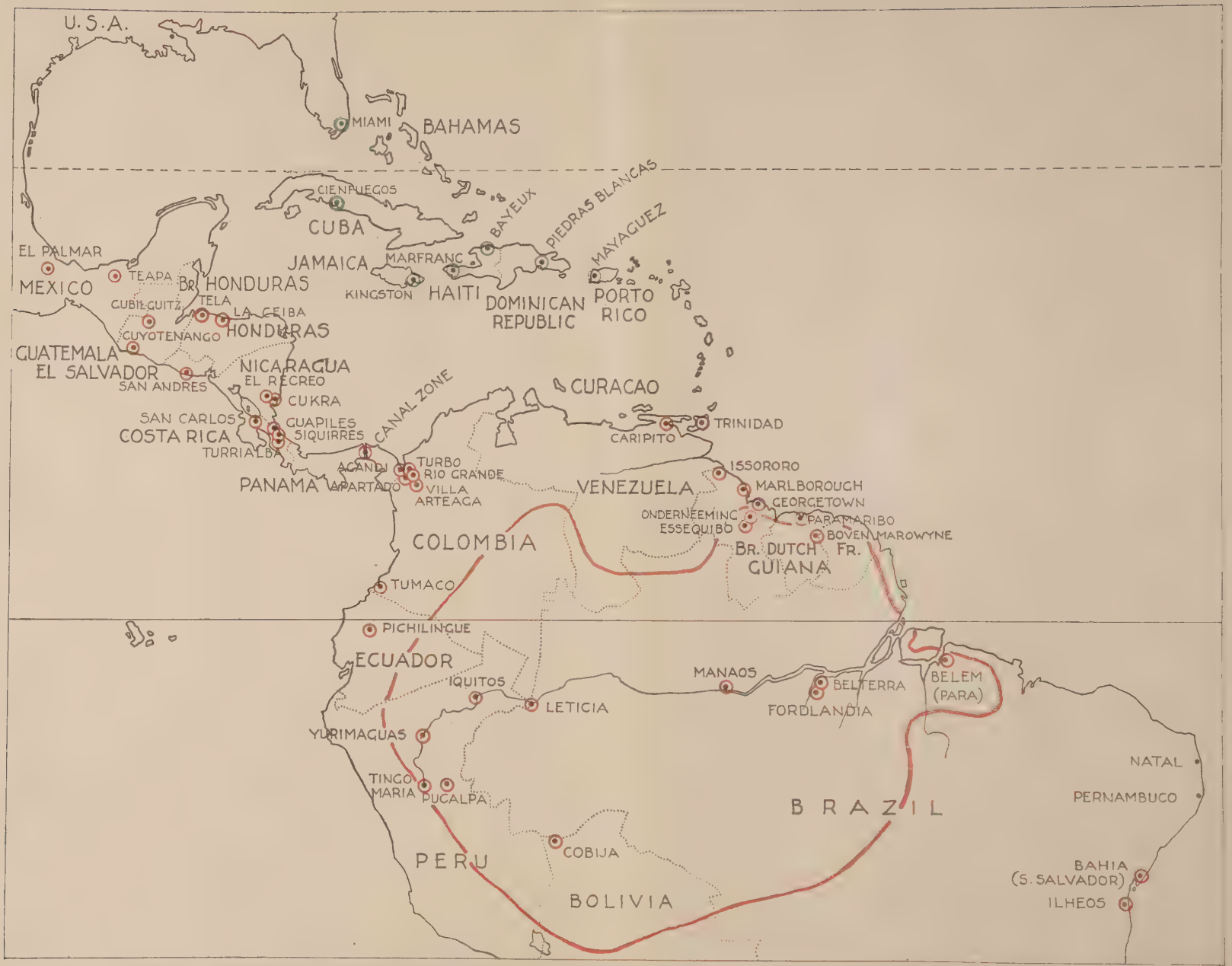


Figure 1. Distribution of Dothidella ulei in tropical America. Red line marks boundary of area to which Dothidella ulei is indigenous. Red circles mark plantings in which Dothidella ulei has appeared. Green circles mark plantings as yet free from Dothidella ulei.

POST-WAR INTRODUCTIONS INTO THE EAST

When the war ended and the experiment stations in the large rubber producing countries of the far east were able to resume their breeding programmes, all were agreed that material of greater genetic variability should be obtained from South America. Plant breeders were anxious to improve yield per tree, and to have material with potential resistance to South American leaf blight; it is known that the Wickham material came from an area in which the trees are particularly susceptible to this disease. Also material from which *Oidium* resistant clones might be bred was required by workers in Ceylon.

With the advent of swift air transport the ease of importing viable material had increased—it was feasible to carry planting material as germinated seed or budwood. Concomitantly there was an increased danger of introducing disease if proper precautions were neglected. No risk was taken in the subsequent introductions however because the hazards involved were fully appreciated. Sufficient breeding material is now growing in Malaya to supply eastern requirements. Seed was disinfected at its place of origin, flown to Kew, disinfected again, and its packaging destroyed. After germination the seed was examined by an inspector of the Ministry of Agriculture, packed in slightly damp peat in sealed tins, and flown to Malaya. On arrival the germinated seeds were washed in a copper fungicide and the containers and peat autoclaved. The germinated seed was planted in nurseries on the Rubber Research Institute premises and kept under daily observation. The 1952 consignments were treated in the same way.

Clones proved in South America to be resistant to leaf blight had to be transferred as budwood or as budded stumps, the former being preferred. Whereas a seed could be germinated at Kew within twenty days, to grow budwood under glasshouse conditions might take two or three years before material suitable for onward transmission was produced. Consequently budwood material was quarantined outside the American tropics, at the U.S. Department of Agriculture Plant Introduction Garden, Coconut Grove, Miami, Florida. Budwood cut in Florida was disinfected with a white oil emulsion (as a precaution against citrus white fly) and with Fermate and flown to Kew. At Kew it was washed, inspected, and dusted with sulphur, before being despatched to Malaya. On arrival the budwood was dipped in 0.2% mercuric chloride in 50 per cent methyl alcohol, washed in running water, dipped again, inspected and passed for budding.

VII LIKELY COURSE OF THE DISEASE IN THE EAST

Speculation as to the behaviour of a disease if introduced to another territory depends primarily upon a knowledge of the causal agent's requirements for infection and growth in its

country of origin. Fortunately full information is available for leaf blight and is given in section II. Most important, and most readily discovered, are the climatic details of the threatened territory. Other factors concern soils, host distribution and the presence of secondary hosts. Distribution and soils are known, but whether there are secondary hosts or not is unknown, as are other more obscure factors, such as parasites of the parasite (more prominent with pests than with diseases).

CLIMATIC FACTORS

RAINFALL—The major portion of the west coast plain on which most of the rubber in Malaya is grown has a fairly even rainfall ranging from a yearly mean of 106 inches at Penang, 85 inches at Kuala Lumpur, to 70 inches in eastern Negri Sembilan. There is a maximum rainfall about October and November (just before the time of the north east monsoon), and a subsidiary maximum about April and May (just before the time of the south west monsoon). In the coastal region of Malacca (yearly mean 87 inches) the maximum is at the height of the south west monsoon, and the minimum at the north east. The situation in Malacca is reversed on the north east coast where most of the yearly 120 inches falls during the north east monsoon.

The mean rainfall figures are similar to those in the South American rubber growing areas, but the distribution is more uneven because of the Monsoon influence. Consequently in most parts of Malaya there is a pronounced 'wintering' season during February to March. The prolonged refoliation period in South America is emphasised in the quotation from R.D. Rands given on page 308. The importance of wintering from the plant pathological point of view is illustrated by the life history of the fungus *Oidium heveae* in the east. This fungus survives throughout the year on scattered flushes, particularly those under shade. It only attains prominence just after wintering, when it develops extensively on the new young leaves, which may drop, bringing about a secondary leaf fall. A heavy attack may defoliate a tree repeatedly, severely weakening it. It has been suggested that *Dothidella ulei* might behave in a similar manner under eastern conditions.

HUMIDITY—Humidity is consistently high throughout Malaya rarely dropping to less than 60 per cent RH even at the hottest part of the day. Tropical American conditions are generally similar. The direct significance of humidity is likely to be its effect on the survival of thin walled air borne spores. Indirectly it is concerned in dew formation.

TEMPERATURE—Temperature is uniform throughout the year in the lowlands of Malaya, falling to a minimum of 70—75°F during the night and rising to a maximum of 85°—90° during the day. These are suitable temperatures for the growth of *Dothidella ulei* as well as *Hevea brasiliensis*.

AIR MOVEMENT—The pattern of winds and rainfall is determined by the monsoons. The north east monsoon is much the

stronger, and has a profound effect on the east coast climate. Local land and sea breezes disguise the effect of the gentler south west monsoon. Between April and November squalls known as 'Sumatras' may strike the west coast, they may do material damage and would be capable of carrying diseased plant debris across the Straits of Malacca. The wind movements in Malaya would certainly carry the disease in from Indo-China or Sumatra were it to break out in those countries first. The local winds would readily disseminate disease throughout the country. However local winds may be advantageous in that they rapidly disperse mists. The prolonged mists described in American rubber growing areas are not known in Malaya.

MISTS AND DEW—As described above, mists are rare in Malaya, and rapidly dispersed. Dew however is usually formed, and frequently lies on the leaves for more than the eight hour period necessary for spores of *Dothidella* to secure infection.

FACTORS OTHER THAN CLIMATE

SOIL—It would be possible from existing knowledge to draw up some comparison of the soils of diseased areas in South America, and those of Malaya. However soil differences have not been demonstrated to affect the course of the disease.

HOST DISTRIBUTION—It was only when hevea trees were grouped together in plantations that the destructive power of leaf blight became apparent. There is no doubt that the continuous belt of hevea from Singapore to Kedah provides ideal conditions for development of the disease.

UNKNOWN FACTORS—Apart from unrecognised variations in known factors which may affect the course of the disease, unknown factors are likely to be of a biological nature. Presence of secondary hosts and absence of indigenous parasites are often of great importance in aggravating the danger of imported insect pests. The same could apply to a fungus disease. So far no secondary host of *Dothidella ulei* is known, and the only parasite is a species of *Botrytis* which is not regarded as playing any part in control.

SPECULATION AS TO THE COURSE OF THE DISEASE IN MALAYA

There have always been workers on rubber in the Americas personally familiar with conditions in the east, and workers in the east who had personal experience of the damage leaf blight could do in its region of origin. The failure of rubber in British Guiana was witnessed by K. Bancroft, who had come from Malaya. W.N.C. Belgrave visited British Guiana in November 1920 on behalf of the Malayan Department of Agriculture. In 1923 R.A. Altson, who was destined to go to Malaya and subsequently to have a great deal to do with organising defence against leaf blight there, arrived in British Guiana. As he served as botanist and mycologist in British Guiana until 1928, he witnessed the last stages of the rubber industry there. A few months after Altson's arrival, R.D. Rands visited British Guiana on

behalf of the U.S. Department of Agriculture (RANDS 1924). Rands worked in Java and Sumatra for some years, and was to become Head Agriculturist in charge of the Bureau of Rubber Plant Investigations. Two members of the U.S. Department of Agriculture's investigation team in the Amazon Valley came to the east, C.D. La Rue to Sumatra, and J.R. Weir to Malaya where he became the first Head of the Pathological Division of the Rubber Research Institute. One of his first acts was to issue warning concerning South American leaf blight (WEIR 1929).

The first published speculations on the likely behaviour of leaf blight if it appeared in the east by someone familiar with its ravages in the west, were by BELGRAVE (1921). He started with the four basic assumptions regarding the life history of the fungus as follows:

i only one of the three forms, the conidial, was capable of reproducing the fungus;

ii the conidia are short lived, possessing no power of resistance;

iii the fungus is, so far as is known, an obligate parasite;

iv infection can take place only on very young leaves.

From this Belgrave concluded that there must be an almost continuous supply of fresh young leaves for the disease to flourish. He pointed out that this was the case in South America, except in unusual years as in 1920 when a drought caused nearly simultaneous wintering. The 1920 situation was similar to that which prevails every year in the Malay States.

Belgrave considered it highly improbable that the fungus would survive a journey to the east because of its non-resistant spores. He also considered that the sharp wintering season would preclude appreciable damage, provided the life history remained unaltered. If the ascospores were to be found functional then the fungus might be able to survive the periods when little or no new foliage is being produced, and repeatedly to do severe damage at mass refoliation. Belgrave therefore recommended extending the existing quarantine restrictions on the import of rubber planting material to include the whole of western rubber growing area (see 'Legislation' page 320).

WEIR (1929) was confident on the other hand that conditions in Malaya were suitable for leaf blight to assume epidemic proportions. He considered that factors of the even temperatures and moisture conditions, together with the extent of susceptible host material, from one end of the country to the other, made leaf blight a very serious prospect. He reiterated Belgrave's warning against imports of planting material unless most strictly controlled.

Assessments made after the war of the danger presented to the far east plantations by *Dothidella ulei* have been based upon much additional knowledge. Not only has far more information about the fungus become available, but there is the record of the steady spread of the fungus from one locality in America to another.

The work of LANGFORD (1945) showed that three of the four premises (page 319) upon which Belgrave predicted the behaviour of the disease were not true. (*i*) The asci were found to be capable of producing fully infective ascospores for weeks. (*iii*) The fungus can now be grown in culture, proving that it is not an obligate parasite, but only under such special conditions that make it seem unlikely that it can exist as a saprophyte in nature. (*iv*) Leaves up to twenty days old can be infected.

A reassessment of the likely course of the disease in the east, made in presenting a case to the Government for revised legislation, is now put forward along with a statement as to what measures have already been proposed to meet the threat.

Looking at the rubber growing areas of the east as a whole (*Figure 2*) it might be thought that the disease could appear in one country in the area without necessarily endangering the others. Experience with *Dothidella* is comparable with blister blight of tea in the orient because both are leaf diseases spread by small thin-walled spores which are produced in vast numbers. Blister blight had been known in Assam for years, spread to Ceylon during the war, and in 1948 appeared in Sumatra and Java—supposed to have been carried by migrating crows. The next year it broke out in the Cameron Highlands area of Malaya.

So far as Malaya is concerned leaf blight would most likely be noticed first in a nursery where it might have begun with two or three lesions two months previously and be causing defoliation at the date of discovery. In the absence of eradicant methods one can assume that the disease would complete destruction of the nurseries within a year. Within that time a wintering would have occurred and the disease probably spread many miles throughout contiguous areas. It is unlikely that mature trees would be killed, but a position similar to that with *Oidium* in Ceylon might arise, the trees being progressively weakened by successive defoliations, and control measures in immature areas a constant source of expense. Death from the disease would be more likely in young replantings and in nurseries, making it impossible to replace old trees without expensive control measures.

VIII LEGISLATION AGAINST S.A.L.B.

The rules and regulations designed to protect a country from a dangerous disease originating in a different region of the world fall into three categories:

i Those giving powers to eradicate the disease should it appear. This is an internal matter affecting only the territory concerned, and the powers would be given to officials of the Government Departments of Agriculture, or equivalent competent authorities.

ii Those designed to prevent diseased material from being imported. Other territories are affected in that trade may be hindered if the wording of the rules is not carefully framed, and if foreign airways and shipping lines

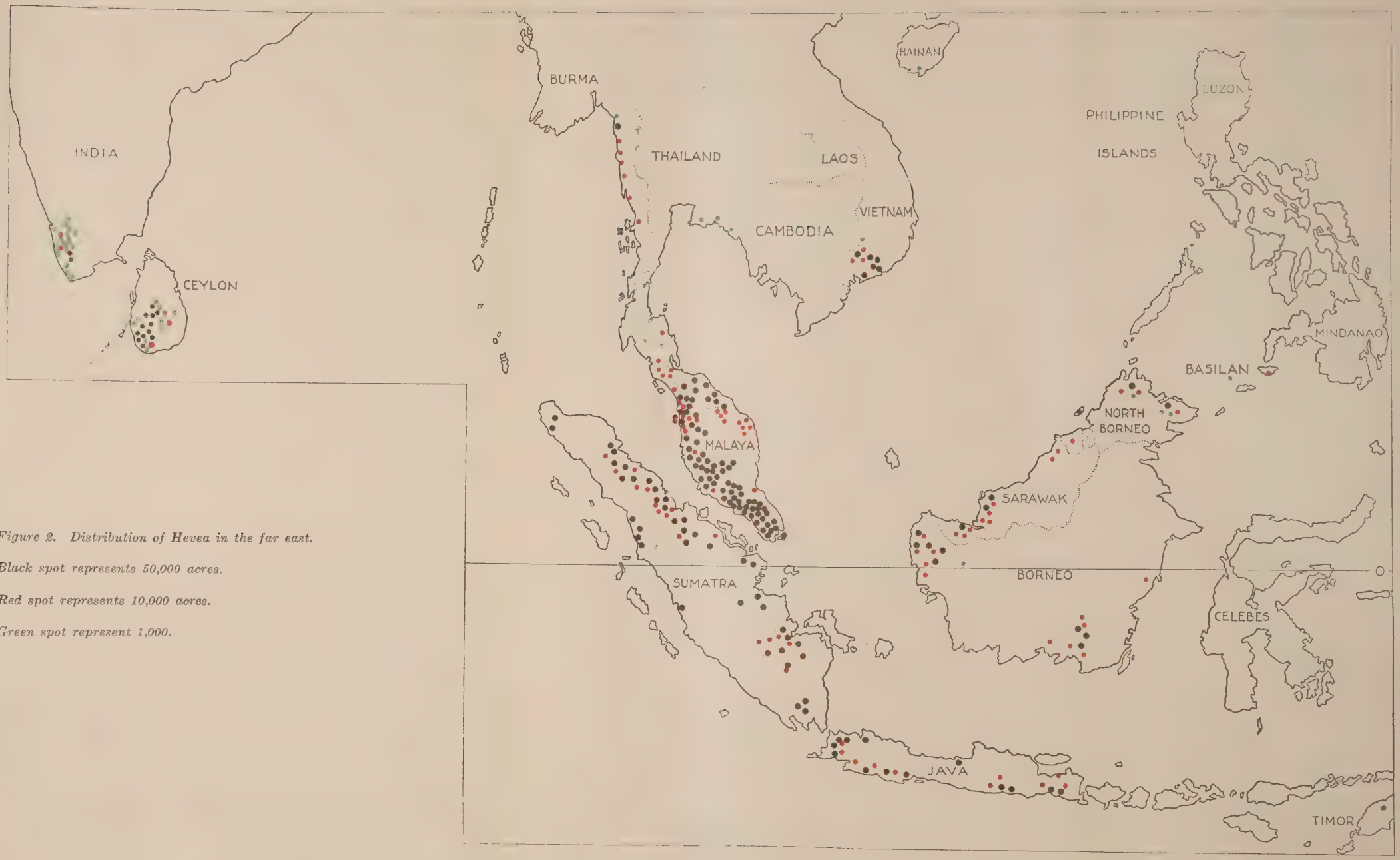


Figure 2. Distribution of Hevea in the far east.

Black spot represents 50,000 acres.

Red spot represents 10,000 acres.

Green spot represent 1,000.

are required to refuse certain types of cargo. An F.A.O. Convention held in 1951 drafted suitable rules for general application. The administration at the points of entry should be in the hands of a special Phytosanitary Service.

iii International regulations in which item (*ii*) above is agreed by all territories within a threatened region so far as the dangerous diseases scheduled are concerned.

The legal position in Malaya at the end of 1947 is stated in Mr R.A. Altson's memorandum reproduced as the *Appendix* to this paper. Powers for eradication could be obtained under a number of State and Settlement enactments, but only after time limits and time for appeal. All imports were prohibited under the Customs Enactment (Malayan Union Government Gazette notification 1191 of 1 August 1946) except under licence, which meant in practice that the Director of Agriculture would be consulted when a licence for import of plants was applied for. There was no international legislation.

The function of the Rubber Research Institute in matters of legislation has been to point out the danger to the rubber industry presented by the unsatisfactory legislation existing in 1947 and to press for adequate local protection and for cooperation on an international scale. To assist in preparing this legislation the Institute has made drafts for the consideration of the Malayan, and other governments in south east Asia, and conferences have been attended by members of the staff in the capacity of advisors or observers.

LEGISLATION CONCERNING ERADICATION

In the F.M.S. Agricultural Pests Enactment of 1934, and in parallel laws of the Straits Settlements, Johore, Trengganu, Kelantan, and Kedah, provision was given for prompt compulsory eradication of any pest or disease declared to be a dangerous pest by Gazette notification. It was considered (*Appendix*) that adequate powers to deal with an outbreak of leaf blight would be given if *Dothidella ulei* were to be gazetted a dangerous pest and if some alteration were made to section 17 so that it would suit a fungus disease as well as locust outbreaks, for which it was designed. Eventually the Agricultural Pests Enactments were revised to become a Federal Ordinance and the modifications were made in the drafts for this. It became the Agricultural Pests and Noxious Plants Ordinance, 1953. On January 7th 1954 South American leaf blight was declared a dangerous pest, together with witches' broom and swollen shoot disease of cacao, and the migratory locust.

PLANT IMPORTATION REGULATIONS

This protection against imports of diseased material provided by the Customs enactment of 1 August 1946, broke down

with the relaxing of restrictions in Gazette Notifications 1258 and 1259 of 29 January 1948. Under the new regulations planting material could be imported from any British territory or any territory in south east Asia under an Open General Licence which had the effect that plants from these territories could be imported without reference to the Director of Agriculture. Further Gazette Notifications followed (No 389 and 390 of 18 March 1948) which excepted Para Rubber and plants whose country of origin is situated within the American tropics, from the rule of plants originating in countries covered by the Open General Licence not requiring an authorisation permit from the Director of Agriculture. These notifications of March 1948 still provide the protection of the rubber industry in law against introduction of material which may carry *Dothidella ulei*. They are administered under the Customs enactment and therefore require Customs' Officials to act as plant protection officers in addition to their normal duties.

It was desirable to frame legislation more specifically aimed at excluding *Dothidella ulei*. To this end Mr R.A. Altson and the Senior Plant Pathologist, Mr A. Thompson, drafted full Plant Importation Regulations to replace those which went with the old enactments.

INTERNATIONAL LEGISLATION

The most effective legislation, but most difficult to secure, is that designed to exclude a disease not only from one country. but from all that country's neighbours. However effective one territory's importation rules and methods of eradication may be, all will be of no avail if diseased material is constantly entering by natural means from sources of infection across political boundaries. The threat of *Dothidella* to south east Asia is a clear case where international agreement is needed. The world map (*Figure 3*) shows the distance between tropical America and the south east Asian region. The distinction between the infected and free areas far from being arbitrary can be precisely defined. *Figure 2* shows the distribution of rubber in S.E. Asia, and how the disease, once established, could not fail but spread from country to country in a matter of time. A similar situation holds for the rubber growing areas within Africa, differing only in the smaller total area planted and the territories having land frontiers instead of being separated by water. An outbreak in Liberia 1,800 miles from an infected area in Brazil, could spread 3,500 miles across Africa to Tanganyika, 2,700 miles from Travancore. It can be seen from the world map how closely linked by air are all these regions.

It was beyond the powers of the Malayan Government to call an international conference and action proposed was put to the Colonial Office, where the whole subject was discussed at the meeting on July 12 1948 (page 291). International cooperation was sought by the United Kingdom Government calling a conference to frame regulations for the countries concerned. It was considered that a phytosanitary convention similar to

that being negotiated for Africa south of the Sahara might be introduced, possibly through the intermediary of the Food and Agriculture Organisation of the United Nations. Whilst calling the conference was the task of the United Kingdom Government, the organisation was conveniently taken over by the Singapore Liaison Officers' Meetings. These meetings initially consisted of technical officers who advised on the distribution of coal, oil, rice *etc*, during the period of shortages which prevailed immediately after the war. Representatives from all countries in the region attended. Later it took the form of a technical advisory committee to the Commissioner General. A sub-committee on plant protection, formed by the twentyfourth L.O.M. on January 6 and 7 1949, had its first meeting on February 22 and 23. Draft regulations prepared by Mr R.A. Altson and Mr A. Thompson were discussed. It was agreed that a phytosanitary convention should be concluded, with these draft regulations as a basis. In addition a permanent advisory committee was proposed to administer the convention. It was suggested that the governments in the region should control all plant imports from tropical America, and should insist on plant material in transit having a permit issued by the country of destination. The twentyfifth meeting of liaison officers took place in March 1949, during which it was announced that the F.A.O. was in favour of the Commissioner General calling a phytosanitary conference. This took place in Singapore on the 26, 27 and 28 April, and was attended by delegates representing the governments of Brunei, Ceylon, Fiji, Hongkong, India, Indo-China, Indonesia, Malaya, Sarawak, Singapore and the United Kingdom.

Although there has not yet been any international agreement signed, not even an agreement restricted to protection against *Dothidella ulei* only, the recommendations of the conference have led to an increased awareness amongst the governments concerned of the danger unrestricted importation of plant material might present to their territories.

Most of the countries in the south east Asia and Pacific Region already had regulations specifically prohibiting importation of *Hevea* without a permit from the Director of Agriculture. Of these Ceylon, Singapore, and Hongkong adopted the recommendations of the conference in restricting import of plants from anywhere in the American tropics. The governments of Fiji, the Federation of Malaya, and Sarawak, have the power to apply all the recommendations under rules prohibiting importation of any plants (with certain exceptions) without the prior sanction of the Director of Agriculture.

A second international phytosanitary conference was convened by F.A.O. and took place in Singapore from 13—17 December 1954. Delegates representing Australia, India, Indonesia, Laos, the Netherlands, Thailand, the United Kingdom, and Vietnam attended. A draft plant protection agreement for the south east Asia and Pacific region was agreed, and in addition a draft appendix to this agreement specifying measures to exclude South American leaf blight of hevea from the region.

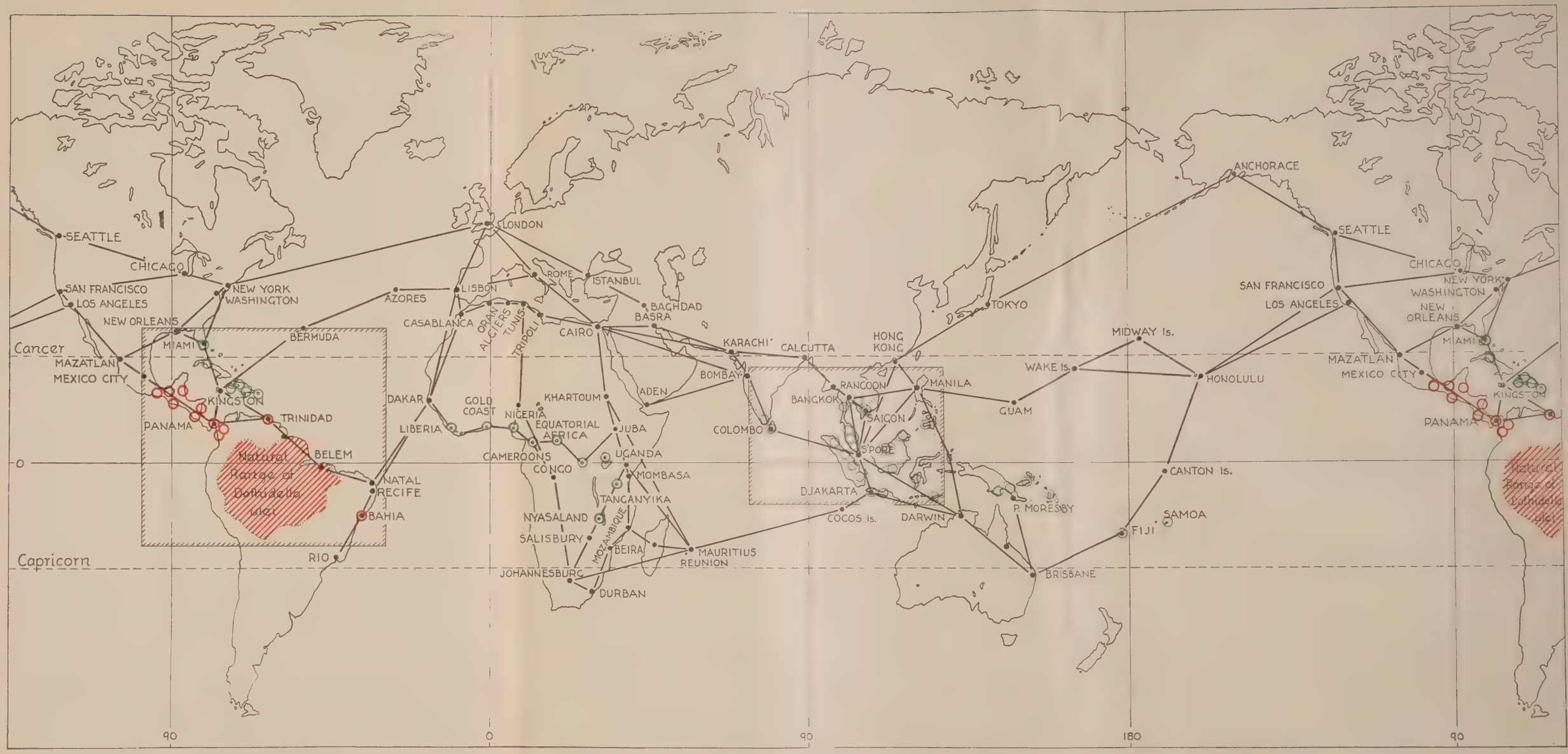


Figure 3. Air links between the World's rubber growing centres. Red cross hatching marks the area to which Dothidella ulei is indigenous. Red circles mark areas to which Dothidella ulei has spread. Green circles mark areas as yet free from Dothidella ulei. Hatched outline indicates areas shown in Figures 1 and 2.

IX ERADICANT MEASURES PLANNED

If there is to be any hope at all of eradicating a disease as virulent as South American leaf blight there must be immediate notification of the outbreak, a ready prepared method of eradication with all equipment and materials for it instantly available, and effective legislation to enforce eradication wherever the disease may break out.

Immediate notification of the disease depends upon all those who have rubber plants in their charge being alert and knowing what to look for. Accordingly, the first requirement for an eradicant campaign is to make the appearance of the disease as widely known as possible and to stress the need for vigilance before the disease breaks out. This was done by publishing an article (PATHOLOGICAL DIVISION 1952) followed by a leaflet with coloured illustrations, both in the R.R.I. Planters' Bulletin. The illustrations were based on water colours by the late Professor R.E.D. Baker, colour photographs by J.B. Carpenter, and herbarium specimens from Kew. The leaflet is reproduced in *Figure 4*. Similar warning literature has been published in Indonesia (VAN HEUSDEN 1953a, b) (PUSAT PERKEBUNAN NEGARA 1953) (TOLLENAAR 1954b) (HOEDT 1953).

Legislation compelling owners to notify and have the disease eradicated from their property, allowing for compensation, is discussed on page 322.

In setting out to find a suitable method of eradicating the disease experiments with a range of herbicides and fungicides were started in 1950 and enquiries were made in Britain amongst those organisations with experience in large scale spraying operations. By the end of 1950 it had become clear that applications of eradicating agent would have to be from aircraft, and that the agent itself should be a herbicide for defoliating the trees (R.R.I. MALAYA 1953). Fungicides were discounted as it would be impossible to ensure the complete effectiveness necessary to eliminate the disease. Aerial application required that the herbicide should be dissolved in oil. The experimental work which led to the selection of 2, 4, 5-T in Shell Diesoline as the eradicating agent, and the Beaver aircraft as the means of applying it was carried out by Mr F.W. Hutchison. It has already been published in the annual reports of the Pathological Division, R.R.I., for 1948, 1949, 1950, and 1951. The experiments with the aircraft operating with the defoliant over old mature rubber are described in the reports for 1952 and 1953.

CHOICE OF METHOD OF ERADICATION—The most thorough applications of fungicide can never be relied upon to kill out a pathogenic fungus completely. More drastic measures are called for and would be justified in a relatively small infected area, the value of which could only be insignificant in relation to the cost to the industry as a whole of failing to destroy the disease. As burning is usually the cheapest and most effective way of destroying infected material, the first trials were carried out with flame throwers. These were found to be useless for destroying living

rubber trees, even in a nursery. The alternative was destruction by chemicals and as *Dothidella* grows only on green tissues investigation was confined to materials that could destroy foliage by direct contact with it. Since the materials would have to be liberated in quantity into the air from readily portable machinery highly poisonous or caustic materials could not be considered.

CHOICE OF MATERIALS—Sodium chloride, a sodium chloride/copper sulphate mixture, and cupric chloride were rejected in preliminary trials. Solutions of ammonium sulphate, sodium chlorate, sodium 2, 4 dichlorphenoxyacetate and sodium dinitro orthocresylate, which defoliated the trees well enough, were rejected because the plants quickly recovered. Recovery was equally swift after Fixanol V.R. and the tar acid compound 'Lotemcide', but initial defoliation was more rapid. Wetting agents failed to improve results with the four compounds in which they were mixed. Further tests were made using sodium pentachlorphenate, the sodium salt of 2, 4, 5-T, and the n-butyl ester of M.C.P.A. Sodium pentachlorphenate caused defoliation only when the leaves were well wetted with it, and the other two substances were more effective defoliants but had little inhibitory effect on refoliation. Water dispersible formulations of the n-butyl-esters of 2,4,5-T and 2,4-D were much more satisfactory, causing complete defoliation and extensive die back within ten days, and inhibiting such refoliation as did occur for about a month.

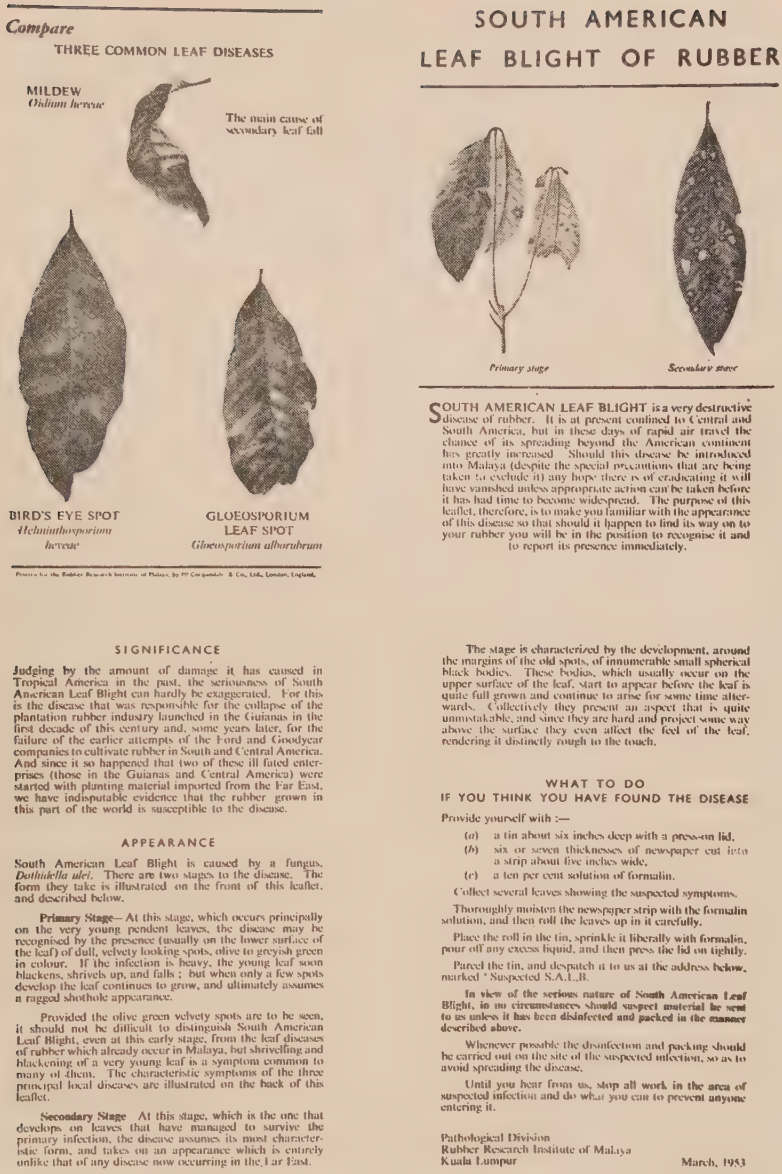
When it was learnt that water evaporates too fast to be suitable as a dispersing medium applied from aircraft, further tests were carried out using the same active ingredients dissolved in oils. Three oils were tested to ensure that they were not sufficiently phytotoxic to defoliate the plants before the solute could be absorbed by the leaf. A gas oil (Shell Diesoline) only scorched the leaf margins; a penetrating oil (Mobil P.O.) and an oil of high aromatic content (P.Y. Sovacide) caused some defoliation but no persistent effect. Each of these three oils was used as a solvent for the normal butyl ester of 2,4,-D, for that of 2,4,5-T, and for pentachlorphenol (which was included for its fungicidal properties, in addition to its phytocidal effect). When these solutions were applied to plots of twelve months old nursery seedlings 2,4,5-T was seen to cause most permanent damage. A mixture of 2,4-D and 2,4,5-T had no advantage over 2,4,5-T alone. The nature of the carrier oil appeared to be of negligible importance, and Shell Diesoline was chosen for large scale trials owing to its ready availability. Several formulations of 2,4,5-T were tested, but none was found to be superior to the n-butyl ester. A 2 per cent solution of the n-butyl ester of 2,4,5-T with .01% pentachlorphenol incorporated was used successfully to defoliate two mature trees when applied by means of a power operated mist blower situated on high ground from which the foliage was accessible. This formulation was selected as the material to be used in large scale field trials.

APPLICATION OF DEFOLIANT FROM AIRCRAFT—Up to the end of the year 1950 it had been the intention to use a Dakota

aircraft fitted with a single orifice emission system as the means of applying the defoliant. This choice had been governed by the Dakota being the only suitable aircraft already operating in Malaya and therefore available at short notice in the event of an emergency. With the introduction of the de Havilland Beaver for the Federation Air Service a more suitable aircraft became available. The Beaver can operate from smaller airstrips than the Dakota and is more manoeuvrable when flying. In addition a spray boom and tank had been specifically designed for it. Government permission to charter a Beaver for spraying trials having been obtained, a set of spraying equipment was ordered from the manufacturers. While waiting for the equipment to arrive preparations were made to calibrate it, following a procedure developed by the Chemical Defence Experimental Establishment at Porton, England. At the same time a Land Rover was fitted with two way radio telephone for ground to aircraft communication, and hydrogen filled balloons, Verey signals, and smoke generators were prepared as markers for spray runs. Experimental spraying commenced in May 1952 with calibration flights, that gave the data from which drop spectrum, swathe width, and rate of deposit could be calculated. The average rate of deposit when flying a one chain swathe at 90 m.p.h. was found to be a maximum of one gallon per acre. In 1953 concentrations of 5, 7, and 10 per cent of the normal butyl ester of 2,4,5-T were sprayed on to old rubber at this rate. The 10 per cent concentration was found to give nearly complete defoliation followed by only slow recovery. To keep the trees leafless it was found that monthly applications were required. Also the technique of spraying was tried out with rubber growing on steeply undulating land and found to work well. Higher rates of application, made possible with new equipment, are to be tested in 1955. This equipment consists of a pump of larger capacity for the boom and nozzle gear and a rotary brush emission unit. The results obtained should determine the details of aerial applications in the proposed eradicant campaign.

SCHEME FOR AN ERADICANT CAMPAIGN—An eradicant campaign would have to be put into action as soon as the occasion for it arose. It must therefore be decided on in advance. An outline of the course that the campaign might take was put forward by the Pathological Division in 1950. Since then the South American leaf blight leaflet issued with Planters' Bulletin 5 has prepared the way for early recognition of the disease, while a revised Agricultural Pests and Noxious Plants Ordinance has given the Department of Agriculture the necessary powers to implement a campaign. As it is desirable that the various implications be widely known the Rubber Research Institute's proposals are given here.

It is foreseen that two kinds of treatment would be needed, one to deal with any infected zone and another with a surrounding guard belt, action in both proceeding simultaneously. The guard belt should be made wide enough to have a good chance of extending well beyond the limit of spread of the infection.



Compare

THREE COMMON LEAF DISEASES

MILDEW
Oidium heveae

The main cause of secondary leaf fall

BIRD'S EYE SPOT
Helminthosporium heveae

GLOEOSPORIUM LEAF SPOT
Gloeosporium alboruburn

Printed for the Rubber Research Institute of Malaya, by [illegible] & Co., Ltd., London, England.

SOUTH AMERICAN
LEAF BLIGHT OF RUBBER

Primary stage

Secondary stage

SOUTH AMERICAN LEAF BLIGHT is a very destructive disease of rubber. It is at present confined to Central and South America, but in these days of rapid air travel the chance of its spreading beyond the American continent has greatly increased. Should this disease be introduced into Malaya (despite the special precautions that are being taken to exclude it) any hope there is of eradicating it will have vanished unless appropriate action can be taken before it has had time to become widespread. The purpose of this leaflet, therefore, is to make you familiar with the appearance of this disease so that should it happen to find its way on to your rubber you will be in the position to recognise it and to report its presence immediately.

SIGNIFICANCE

Judging by the amount of damage it has caused in Tropical America in the past, the seriousness of South American Leaf Blight can hardly be exaggerated. For this is the disease that was responsible for the collapse of the plantation rubber industry launched in the Guianas in the first decade of this century and, some years later, for the failure of the earlier attempts of the Ford and Goodyear companies to cultivate rubber in South and Central America. And since it so happened that two of these ill fated enterprises (those in the Guianas and Central America) were started with planting material imported from the Far East, we have indisputable evidence that the rubber grown in this part of the world is susceptible to the disease.

APPEARANCE

South American Leaf Blight is caused by a fungus, *Dothidella ulei*. There are two stages to the disease. The form they take is illustrated on the front of this leaflet, and described below.

Primary Stage— At this stage, which occurs principally on the very young pendent leaves, the disease may be recognised by the presence (usually on the lower surface of the leaf) of dull, velvety looking spots, olive to greyish green in colour. If the infection is heavy, the young leaf soon blackens, shrivels up, and falls; but when only a few spots develop the leaf continues to grow, and ultimately assumes a ragged shothole appearance.

Provided the olive green velvety spots are to be seen, it should not be difficult to distinguish South American Leaf Blight, even at this early stage, from the leaf diseases of rubber which already occur in Malaya, but shrivelling and blackening of a very young leaf is a symptom common to many of them. The characteristic symptoms of the three principal local diseases are illustrated on the back of this leaflet.

Secondary Stage At this stage, which is the one that develops on leaves that have managed to survive the primary infection, the disease assumes its most characteristic form, and takes on an appearance which is entirely unlike that of any disease now occurring in the Far East.

The stage is characterized by the development, around the margins of the old spots, of innumerable small spherical black bodies. These bodies, which usually occur on the upper surface of the leaf, start to appear before the leaf is quite full grown and continue to arise for some time afterwards. Collectively they present an aspect that is quite unmistakable, and since they are hard and project some way above the surface they even affect the feel of the leaf, rendering it distinctly rough to the touch.

WHAT TO DO
IF YOU THINK YOU HAVE FOUND THE DISEASE

Provide yourself with :—

(*a*) a tin about six inches deep with a press-on lid,
(*b*) six or seven thicknesses of newspaper cut into a strip about five inches wide,
(*c*) a ten per cent solution of formalin.

Collect several leaves showing the suspected symptoms.

Thoroughly moisten the newspaper strip with the formalin solution, and then roll the leaves up in it carefully.

Place the roll in the tin, sprinkle it liberally with formalin, pour off any excess liquid, and then press the lid on tightly.

Parcel the tin, and despatch it to us at the address below, marked 'Suspected S.A.L.B.

In view of the serious nature of South American Leaf Blight, in no circumstances should suspect material be sent to us unless it has been disinfected and packed in the manner described above.

Whenever possible the disinfection and packing should be carried out on the site of the suspected infection, so as to avoid spreading the disease.

Until you hear from us, stop all work in the area of suspected infection and do what you can to prevent anyone entering it.

Pathological Division
Rubber Research Institute of Malaya
Kuala Lumpur

March, 1953

Figure 4. Reproduction of warning leaflet issued in Planters' Bulletin 5.

A depth of a quarter of a mile is proposed. The aim in treating it would be to defoliate the trees and keep them leafless long enough for any fungal material in the circumscribed area to die out. Defoliation would be achieved as already determined by spraying from the air with an oil solution of 2,4,5-T. The exact

concentration and rate of application are still to be determined by aerial spraying trials for which plans have been made. To treat the guard area expeditiously the rate of deposit should be kept as low as is consistent with effectiveness. It may be unnecessary to increase the volume much above one gallon per acre. This is too small an amount to be made fungicidal as well, therefore a separate aerial application of pentachlorphenol dissolved in oil is proposed as a further precaution. It would be necessary to leave an interval, which has been estimated at one day, between the defoliant and fungicidal applications, lest leaf fall induced incidentally by the fungicidal spray remove a substantial amount of the hormone from the trees.

According to LANGFORD (1945) conidiospore production on infected leaves ceases after three months, ascospores being produced between three and five months. Both types of spore are short lived. It is therefore proposed that the guard belt be kept leafless for six months. Repeat applications of the defoliant within this period would be made when incipient refoliation showed them to be required. The interval between applications would depend to some extent on the concentration of the active ingredient and on the rate of deposit decided on. Past experience suggests that sprayings would need to be at intervals of approximately one month. On the supposition that the fungicidal treatment would not be fully effective, the fallen leaves in the guard belt would be burned at the first opportunity.

The aim in treating an infected zone would be the rapid destruction of the fungus along with the host plants in addition to the initial aerial spraying. In a nursery or young field planting the treatment proposed is drenching with a near saturated solution of pentachlorphenol in oil, using power driven ground equipment. As soon as possible after spraying the area would be felled and burnt, if necessary applying more oil to get a good burn. If the disease were to be discovered in mature rubber these additional procedures would have to be modified somewhat. Following defoliation from the initial spraying, a further and heavier aerial application of 2,4,5-T would be desirable, to kill the trees quickly so that the inevitable delays in felling and burning would not create a serious hazard.

Fallen leaves in the guard belt would be closely inspected for leaf blight lesions. Should the disease be found to have spread beyond the known infected zone it would be necessary to increase appropriately the size of the treated area. Inspections of rubber outside the guard belt would be carried out over a distance of a mile or two, and would be guided by an estimate of the direction in which spread of the disease would be most likely, on grounds of topography and prevailing winds. Most attention would be given to young rubber where the disease would be easier to see. It is unlikely that leaf blight could be detected in mature rubber until the first period of wintering and refoliation after it had become established. For this reason the secondary leaf fall survey carried out every year in Malaya by the Rubber Research Institute is doubly valuable.

It is suggested that eradication should not be attempted if ever the disease became established in Sumatra or in southern Siam, because of the danger of repeated introductions from sources as close as this.

X DOTHIDELLA RESISTANT MATERIAL

To establish budwood multiplication nurseries for *Dothidella* resistant material was clearly one of the first requirements for protection of the eastern rubber industry. Not only would the material be vital were the disease to arrive but at once it would have a value in reducing the chance of unauthorised importation of supposedly resistant material.

Dothidella resistant clones had been developed in the Americas but its export was prohibited under an agreement between the countries that had cooperated in its production. At the Colonial Office meeting on July 12 1948 (page 291) it was proposed that the American cooperating countries should be approached to ascertain whether they would lift the embargo. At the same time the Department of Agriculture, Trinidad was to be asked to investigate the setting up of a breeding and testing station there. On September 3 the Director of Agriculture, Trinidad, (Mr E.W. Leach) and the Principal of the Imperial College of Tropical Agriculture (Mr H.J. Page) met the Director of the R.R.I. at the Colonial Office and discussed both the embargo and the plans for a testing station. They agreed on the establishment of a substation in Trinidad for breeding work and for the testing of the newer Malayan selections for any resistance they might show. Information from the United States Government indicated that the embargo could not be lifted without the agreement of all the cooperating countries. Accordingly plans went ahead for the establishment of a substation in Trinidad, and in January 1949 the first lot of seed was sent from Malaya to Kew for raising stocks on which material to be grown in intermediate quarantine could be budded.

During the year 1949 information was received that the Brazilian Government had not signed the Inter-Governmental Memorandum of Understanding preventing export of *Hevea* material, and that traffic in *Hevea* was still controlled under Brazilian Decree Law 7946 of September 10 1945. This law expressly allows the Director of the Instituto Agronomico do Norte at Belem to export *Hevea* from Brazil, but only to scientific institutions in exchange for other planting material.

Early in 1950 arrangements were made for the Head of the Pathological Division, Mr R.A. Altson, to visit America to study the work of the U.S.D.A. Cooperative Rubber Project in the Western Hemisphere, and to discuss the question of an exchange of planting material with Dr Felisberto C. de Camargo, Director of the Instituto Agronomico do Norte.

On his arrival in the United States at the beginning of September 1950 Mr Altson attended meetings held at the U.S.D.A. both in Washington and Beltsville. These meetings had been

arranged by Dr R.D. Rands for the purpose of discussing, among other things, in what way the U.S.D.A. could further Malaya's aims without offending the terms of the Memorandum of Understanding. The representatives of the U.S.D.A. were willing to allow the quarantine station at Coconut Grove, Florida, to be used for intermediate quarantine of any hevea material that Brazil might offer.

Mr Altson left New York for Trinidad on 13 September, from which he made a four day visit to the Instituto Agronomico at Belem, Brazil. Dr Camargo expressed his willingness to exchange a number of Dothidella resistant clones (which were to be nominated later) for an equal number of R.R.I. clones and certain selected strains of padi and oil palms.

After leaving Trinidad Mr Altson visited Panama and then Costa Rica where he was shown the work being done under the Cooperative Rubber Project and had the opportunity of obtaining Dr M.H. Langford's advice on the choice of Dothidella resistant clones intended for introduction into Malaya. The clones that have since been introduced were selected on the basis of Dr Langford's recommendations.

On October 19 1950 a meeting took place in Dr Sasscer's office in Washington at which Dr Rands, Dr Fracker, Dr. Wheeler, C.E.T. Mann, and R.A. Altson were present. Details of the part the U.S. Department of Agriculture was to play in the exchange were discussed, particularly the arrangements at Florida which was to replace Kew as the site for growing material in intermediate quarantine outside the American tropics. Since the budwood was to travel from Florida to Malaya, with only repacking and not intermediate quarantine at Kew, it was necessary to take into account any disease or pest present in Florida and not in Malaya. The U.S.D.A. Bureau of Entomology and Plant Quarantine recommended a proprietary white oil product for treating budwood against citrus white fly and this was subsequently used prior to Fermate treatment on the shipments for Malaya. Correspondingly it was important that the exchange did not bring any Asiatic pest or disease into the Americas, *Oidium heveae* being the most obvious disease to guard against. The American requirements were for the far east budwood to be dipped in alcoholic mercuric chloride.

By the middle of 1951 arrangements for the exchange were complete. Rands instructed his field locations in the procedure to be adopted, and the Botanical Division of the R.R.I. prepared to take over the arrangements for exchange from the Pathological Division. The latter Division continued to be responsible for inspecting and disinfecting both incoming and outgoing material.

Arrival of this resistant material has enabled the Botanical Division to work out a breeding programme aiming to combine yield with resistance. In December 1954 the first clones became available for distribution to other organisations in the east, enabling them to go ahead with their own programmes.

The author wishes to express his indebtedness to Dr A. Newsam, Head of the Pathological Division, for constant advice throughout the course of the preparation of this review; to Mr R.A. Altson, former Head of the Pathological Division, and Mr C.E.T. Mann, Director of the Rubber Research Institute, for reading the manuscript and providing much information that has been incorporated within it.

All the illustrations have been prepared by Mr Hoh Choo Chuan, artist and photographer of the Institute.

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APPENDIX

MEMORANDUM

SOUTH AMERICAN LEAF DISEASE OF RUBBER

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In view of the growing menace of South American leaf disease, due more particularly to the ever increasing volume and speed of air traffic, it is considered desirable that attention should be drawn to:—

(a) the magnitude and reality of this potential threat to the Malayan rubber industry

(b) the means at our disposal for defence against the introduction of the disease, and

(c) the measures which might be adopted to deal with it should it once become established.

THE MAGNITUDE AND REALITY OF THE THREAT

2. South American leaf disease of rubber is not only the most serious disease to which *Hevea brasiliensis* is subject, but it has shown itself to be one of the most destructive diseases of cultivated plants of which there is any scientific record. Indeed, the scale of its past devastations ranks it with such plagues as the epidemic of potato blight which caused a famine in Ireland one hundred years ago, and the outbreak of rust that destroyed the coffee industry of Ceylon in the eighties of the last century. Its ravages have already been responsible for the total collapse (within ten years of its initiation) of a plantation rubber industry that was launched in the Guianas in the first decade of this century, and, some years later, for the utter failure of the earlier attempts of the Ford and Goodyear companies to cultivate rubber in South and Central America. The significance of the fact that two of these ill-fated enterprises (those in the Guianas and in Central America) were based on planting material imported from the Far East needs no emphasis.

3. A remarkable feature of these outbreaks was the astounding rapidity with which the disease brought about the destruction of the crop. There is a case on record (Stahel, G.West-Indie Landb. Tijdschr. Suriname en Curacao, 4: 63, 1919.) where within six months of its appearance in an epidemic form in a 200 to 300-acre stand of young rubber one-third of the trees were dead, and the rest in such a hopeless condition that the area was subsequently abandoned. It is now realised, of course, that the undertakings in the Guianas and the Ford project in Brazil were all predestined to attack, for potential sources of infection were already present on the wild Heveas growing in the surrounding

forests. But this was not the case with the Goodyear plantations in Panama and Costa Rica; here the appearance of the disease was due entirely to its introduction by human agency.

4. Seeing that the plantation rubber industry in the Far East has been faced with the threat of South American leaf disease during the whole course of the fifty years of its existence and has so far escaped unscathed, it might well be thought that the realities of the threat have been grossly exaggerated. It is believed that it will be possible to show that this, unfortunately, is not the case.

5. South American leaf disease is endemic in northern South America, its natural distribution being coincident with the distribution of the genus *Hevea*. It is caused by an obligate[1] fungal parasite, *Dothidella ulei*, whose life history is characterised by three distinct reproductive stages. Of these, the first to appear is the conidial stage (*Fusicladium macrosporum*), during which vast numbers of naked spores are borne (in acervuli) on both surfaces of the infected leaves. In the two stages which follow this—the pycnidial stage (*Asposphaeria ulei*) and the perfect or perithecial stage (*Dothidella ulei*), the spores are produced in the interior of spherical fruit bodies.

6. That the disease is able to assume epidemic form is probably due almost entirely to the reproductive mechanism provided by the conidial or *Fusicladium* stage, which for this reason has rightly come to be regarded as the most important of the three. Stahel (Dept. Landb. Suriname. Bul. No. 34. 1917) to whose researches we owe much of our knowledge of the life history of the pathogen, found that the viability of the detached *Fusicladium* spore is of extremely short duration, and that in the event of its failure to germinate and secure penetration of the host tissue, it is liable to succumb to desiccation within a matter of fifteen hours.

7. This observation is of great significance for it leads to the conclusion that the disease is unlikely to be transmitted by this form of spore over anything but short distances—*except in circumstances where material bearing Fusicladium lesions is transported at high speeds.* For instance in fifteen hours a modern transport aircraft can travel 2,500 to 3,000 miles, and in this way Malaya has now been brought within critical range (so far as the *Fusicladium* spore is concerned) of all the rubber cultivations of the Far East, including the Goodyear plantations at Zamboanga in the Philippines. The latter area is to be regarded with particular suspicion because of the likelihood of traffic in planting material between it and the *Dothidella*-infected properties owned by the same company in Panama and Costa Rica.

8. The introduction of the disease into these two Central

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[1] It has recently been reported that *D.ulei* has been grown on an artificial medium (Honig, P. *et alii*, Chronica Naturae. 103(5): 63, 1947).

American republics[1] took place only about ten years ago. Both countries are well north of the natural range of *Dothidella ulei* and the fungus must therefore have been introduced with planting material brought from Brazil. What form this took is not known, but as the whole object of the Goodyear enterprise seems to have been the establishment of Far Eastern clones, it was in all probability as seed intended to provide stocks for budding. Now since Para, the main terminal in northern Brazil, is about 2,500 miles from Colon in the Canal Zone, we have what appears to be definite evidence that despite all reasonable precautions (which we may be sure were taken) the fungus can be transported in a viable and infective condition over extremely long distances.

9. It might be thought—in fact it has been thought, that as the detached *Fusicladium* spore is so short-lived, regulations which prevent the transport of planting material by air are a sufficient defence against the introduction of the disease. But this would only be the case if the fungus were entirely dependent on the *Fusicladium* spore for its reproduction an assumption which, surprisingly enough, has been made on more than one occasion in the past on the basis of what is very slender and questionable evidence. The truth is that opinion regarding the significance of the two other spore forms of the parasite has been biased by the fact that Stahel failed to obtain experimental infection with either, this negative result being quite unjustifiably interpreted as proving that the pycnospores of *Asposphaeria ulei* and the ascospores of *Dothidella ulei* play no part in the propagation of the species.

10. In temperate regions the perithecial form of a fungus constitutes a resistant resting stage, and it is in this state that many well-known plant pathogens are able to survive the winter, despite the absence of suitable host tissue. Thus on the grounds of analogy alone it would more reasonable to suppose that the perithecia of *Dothidella* play some part in the survival of the species, than to dismiss them as being of no importance. But as it happens we are not entirely dependent on analogy for such an opinion. In 1926, nine years after Stahel had published his researches, Weir (U.S.D.A. Dept. Bul. No. 1380, 1926) reported the finding of fertile perithecia on 3-year old stem cankers during the course of a survey in the Amazon valley and, on account of this observation, reached the conclusion that viable mycelium capable of producing perithecia might survive in a branch up to a period of three years. Furthermore, he threw doubt on Stahel's work by inducing an infection with the aid of ascospores; a result, however, that he himself described as being "far from conclusive", owing to the absence of sufficiently rigid experimental conditions. Nevertheless, in the face of these observations it

[1] The appearance of *D.ulei* at Teapa in southern Mexico in September, 1946, has just been reported (Rev. Appl. Myc. 26: 417, 1947). This is about 800 miles north-west of Turrialba in Costa Rica, its previous northermost limit.

would be most unwise to assume that either the perithecia or their ascospores are functionless, or to forget the possibility that the fungus might even survive in a dormant vegetative form.

11. It will be natural to ask how the possession of these effective resting stages by *Dothidella* can be reconciled with the fact that the Far East has so far managed to avoid the disease. This immunity may be attributed in the first place to the fortunate circumstance that the original introductions of planting material from South America consisted of plants which had been raised from seed germinated at the Royal Botanic Gardens, Kew, and had thus been subjected to the most rigorous and effective form of quarantine that can be devised; and secondly to the efficacy of the regulations controlling the imortation of plants, which were subsequently brought into force by all the Governments concerned.

12. A few direct introductions of *Hevea* seed from South America have taken place since the original importations were made in the seventies of the last century. de Vries (Proc. 4th Pacific Sci. Congr. Java. 4: 157, 1930) records five such introductions into Java between the years 1896 and 1915. In 1920, Harrison (S.S. Gardens Bul. 2: 205, 1918-21) recalled that a few seeds of *Hevea confusa* had been sent from British Guiana to the Botanic Gardens, Singapore, sometime between 1898 and 1900, and, finally, there is evidence (Masefield *in litt.*) that a consignment of seed was brought into Ceylon from Brazil in 1907, though it is not clear whether this was a direct importation or not.

13. Attention is drawn to this record because it needs to be realised that the knowledge that seven direct importations have been made in the past without any disastrous results has tended to encourage a belief that the danger of introducing *Dothidella* on planting material, and particularly on seed, has been much exaggerated. Actually, all that the record does indicate is that transmission of the disease in a consignment of unquarantined seed is not an ineluctable event, but one that is determined by chance. It is, of course, impossible to say what odds are involved, but even if they were as much as a thousand to one, we still cannot afford to indulge in the gamble, for the stakes are too high.

14. It will not be forgotten that the plantations which were destroyed by South American leaf disease in the Guianas consisted of trees raised from seed imported from Malaya and Ceylon, or that recent observations carried out in Brazil and Central America have shown that all the high-yielding Far Eastern clones are extremely susceptible to the disease. In view of these facts, one cannot escape the conclusion that should *Dothidella* become established in this country, and spread with the astonishing rapidity which characterised the course of its epidemic in the Guianas, the not improbable sequel might be the ruin of the present Malayan rubber industry.

15. There are but two ways in which the menace of South American leaf disease can be met. First, by subjecting all importations of planting material to a rigid system of control in the hope of preventing its introduction, and, secondly, by the gradual replacement of the existing susceptible trees by *Dothidella*-resistant varieties. The former of these two methods is by far the most important by reason of the fact that it is capable of immediate application. The universal adoption of disease-resistant clones represents the ideal form of defence, but, as will be shown later, many years must elapse before the problem can be solved in this manner.

1. *Control of the Importation of Planting Material*

A. *The Present Position*

16. Before the war the importation into Malaya of "growing plants . . . and any parts thereof from which further plants might be propagated" was governed by F.M.S. Gazette Notification No. 1823 of the 1st May, 1936, (which derived its authority from Section 121 of the Customs Enactment, 1936), by S.S. Gazette Notification No. 1485 of the 29th May, 1936 (which derived its authority from Section 18 of the Agricultural Pests Ordinance) and by parallel legislation enacted in the five Unfederated States.

17. The position at the moment is that all these pre-war regulations are still operative; and this is so despite the fact that the relevant F.M.S. Gazette Notification has since been cancelled by M.U. Gazette Notification No. 1191 of the 1st Agust, 1946. The latter, it is important to note, provides for the total prohibition of all importations whatsoever *except under licence issued by the Comptroller of Customs*. The peculiarity of this situation has, however, been rectified by an *ad hoc* arrangement that all questions of plant importation shall be referred by the Comptroller of Customs to the Director of Agriculture.

18. Consequent on the continued existence of this plurality of legislation, the importation of planting material into Malaya is thus still controlled by seven sets of regulations, which, although they agree in their main provisions, differ in some important details. They all agree in prohibiting:—

(a) the importation of any plant by aircraft.

(b) the importation of any plant by sea or land except through specified ports or places of entry (with the exception of the States of Trengganu and Perlis which prohibit the importation of scheduled plants only).

(c) the importation of certain scheduled plants by sea or land except in accordance with prescribed conditions.

19. They differ, however, in the following respects:—

(i) *Exceptions to the prohibition of importations by air.* Cut flowers may be imported by air from the Netherlands Indies, (a) into the S.S., Johore and Kedah provided they are not portions of any scheduled plant and that they are landed at the

ports or aerodromes of Singapore, Penang, Johore Bahru and Alor Star respectively; and (b) into the F.M.S. by virtue of a permit issued at the discretion of the Director of Agriculture. Any plant may be brought into Kelantan by air for scientific purposes with the written permission of the State Agricultural Officer given with the approval of His Highness the Sultan. In Trengganu and Perlis there are no exceptions to the prohibition of importations by air.

(ii) *Ports and places of entry.* There are no less than twelve legal ports and places of entry, namely, Singapore, Penang, Port Swettenham, Johore Bahru, Muar, Kota Tinggi, Alor Star, Kodiang, Bukit Kayu Itam, Tumpat, Kuala Lumpur and Kota Bharu, the last two being specifically places to which scheduled plants imported by parcel post are to be addressed.

(iii) *Conditions governing the importation of scheduled plants.* Scheduled plants, which include all species of *Hevea*, may be imported with the written permission of certain specified authorities, which permission must be obtained prior to the despatch of such plants from the country of origin. These authorities are: for the former F.M.S. and S.S.—The Director of Agriculture or the Chief Field Officer; for the States of Johore, Kedah and Kelantan—the State Agricultural Officers, for the States of Trengganu and Perlis—the State Councils. The issue of this written permission is subject to the following conditions:—

(a) That every consignment of plants is accompanied by a certificate in a prescribed form signed by an approved person (except in Trengganu and Perlis where the need for a certificate is not specified). The form of certificate prescribed for use in the F.M.S., S.S., and Johore differs from that prescribed for use in Kedah and Kelantan, but in both cases all that is demanded is a general declaration of freedom from diseases and pests.

(b) That every consignment of plants is examined on arrival by a specified authority who has the power to decide whether the plants shall be delivered to the importer, quarantined, disinfected, or destroyed (except in Trengganu and Perlis where no such provision is made). All these specified authorities are officers of the Department of Agriculture, except in the case of the former S.S., where in addition to the Agricultural Officers, Singapore, and Penang and Province Wellesley, authority is also delegated to the Director and the Assistant Director of Gardens, Singapore, and the Assistant Curator of Gardens, Penang.

20. Overriding all these regulations are powers given, in the case of the F.M.S. and S.S., to the Director of Agriculture, and in the case of Johore, to the State Agricultural Officer, to permit the importation of any plant for scientific purposes by any route whatsoever.

B. *Recommendations relating to the Existing Regulations*

21. In view of the state of the existing legislation (as outlined in the foregoing summary), it is difficult to avoid the conclusion that the importation of *Hevea* planting material cannot be subjected to a truly rigid system of control under present con-

ditions. Such a result might perhaps be achieved with the willing co-operation of everyone concerned, but the present machinery is clearly quite incapable of coping with any determined intention to evade the law.

22. What appear to be the more outstanding gaps in the system (which forms, it is to be remembered, our only line of defence against South American leaf disease) are listed below, together with suggestions for their closure.

(i) *The delegation of the overriding authority relating to importations for scientific purposes.* This extremely important power should be confined to the Director of Agriculture in person.

(ii) *The delegation of authority relating to the granting of permits for the importation of scheduled plants.* This authority should be confined to the Director of Agriculture and to the Chief Field Officer.

(iii) *The multiplicity of ports and places of entry.* All necessary importations of planting material into Malaya could without any inconvenience be restricted to the Ports of Singapore, Port Swettenham and Penang.

(iv) *The form of the prescribed certificate.* This is couched in too general terms. In the case of *Hevea* planting material it should demand not only a general declaration of freedom from diseases and pests, but a specific declaration to the effect: (a) that the material is free from South American leaf disease (*Dothidella ulei*) and from *Phytophthora* leaf disease, and from any other diseases or pests which it may be considered desirable to add; and, (b) that the country in which it was grown is likewise free from such specified diseases and pests. A certificate in this form has been demanded by the Government of the N.E.I. since 1931, and (in so far as *Dothidella* is concerned) by the Government of India since 1940.

(v) *The exception which permits the importation of cut flowers by air from the N.E.I.* As will be shown later, there is good reason to suspect that attempts may be made, in the not very distant future, to smuggle *Hevea* budwood into Malaya. No more convenient vehicle could be imagined than a box or basket containing cut flowers. Not only would this provide an ideal environment for maintaining the budwood in a healthy condition, but the importer could rely on the delicate nature of the ostensible cargo precluding a thorough examination by Customs.

(vi) *The unsatisfactory state of the legislation in Trengganu and Perlis.* This hardly needs emphasis, particularly in the case of Perlis part of whose boundary marches with the Siamese frontier.

C. *Additional Recommendations*

23. Except under the most carefully controlled conditions (which are inapplicable to large scale commercial introductions), the importation of planting material must invariably be attended by a certain element of risk. Since this risk is borne, not by the importer alone, but by the whole industry, it is held that in view of the grave menace of South American leaf disease (which will tend to grow with the increasing volume and speed of air traffic)

the time has now been reached when it is no longer justifiable to permit the introduction of *Hevea* planting material from any source whatsoever, unless it can be shown that such an introduction is essential to the well-being of the Malayan rubber industry as a whole. The suggestion is made, therefore, that the issue of a permit to import *Hevea* planting material should in future be granted by the Director of Agriculture only on the recommendation of a committee consisting of himself, as Chairman, the Director of the Rubber Research Institute, and one representative each of the estates and smallholders.

24. While this provision should go a long way towards safeguarding the local industry, it would be imprudent to regard it as sufficient in itself. For Malaya to continue to maintain its freedom from South American leaf disease, it is considered essential that an absolute embargo should be imposed on *all direct* importations of planting material *of any sort* from tropical America. The reason for suggesting that this embargo should include all plant species, and not only all species of *Hevea*, is a belief that the dissemination of plant disease can take place through the accidental inclusion in consignments of planting material of infected plant debris that has been derived from a species other than the one intended for despatch, an event which may occur when the two are growing in close proximity. No system of inspection can, of course, guard against such fortuitous introductions, and the only sure safeguard is quarantine well outside the country, or group of countries, which it is desired to protect.

Note. During the course of a meeting held at the Department of Agriculture on the 11th December to discuss the proposed embargo on direct introductions from tropical America the question was raised of the importation into Malaya (for the purposes of human consumption) of grape-fruit from Trinidad and of rice from Brazil. Strictly speaking neither of these are importations of planting material, though both, of course, might be used for that purpose. However, considering the care that has to be exercised in preparing and packing citrus fruit for export, the risk of infected plant debris being included in such a consignment may be dismissed as negligible; and in so far as the importation of Brazilian rice is concerned, it is understood that this crop is grown for export only in the States of Sao Paulo and Rio Grande do Sul, the northernmost of which is some 1,500 miles south of Para and thus well outside the natural range of *Hevea* and the known range of *Dothidella ulei*.

25. Once this proposed embargo was in force, Malaya's own line of defence against South American leaf disease could be considered complete, but a moment's thought will show that such unilateral action is not enough. Should *Dothidella ulei* appear anywhere in the Far East, a perfected system of plant import control might still continue to protect this country's rubber cultivations for a number of years, but they would truly have reached that stage in their history (which in the opinion of a senior official of the United States Department of Agriculture has

already arrived[1]) when the inexorability of their fate would be no longer in doubt.

26. Because of this inevitable interdependence of all the rubber growing countries of the Far East, it is held to be urgently desirable that an approach be made to all the Governments concerned with the object of formulating an international agreement which will ensure that the Far East as a whole places a total embargo on all direct importations of Hevea planting material from tropical America, and permits, for scientific purposes, only such introductions as have been subjected to an approved form of intermediate quarantine carried out preferably in Europe.

2. *Use of Dothidella-resistant clones*

27. The destructive effect of South American leaf disease. experienced first in the Ford Company's plantations in Brazil and then on the Goodyear properties in Panama and Costa Rica, convinced the Americans that if the cultivation of *Hevea brasiliensis* was ever to succeed in tropical America, the industry would have to be based on the use of *Dothidella*-resistant material; and consequently for some years now they have been devoting much attention to the question of its selection and breeding. At the moment, the plantations in South and Central America are being established with high-yielding Far Eastern clones top-budded with resistant strains, but this is only a temporary expedient, and the ultimate aim of the project is the development of clones combining high-yield with disease-resistance.

28. The introduction of this *Dothidella*-resistant Hevea into the Far East will appeal to many as the most obvious way of protecting the cultivations in this part of the world from South American leaf disease—but there are several obstacles to be overcome before this solution of the problem can be reached. In the first place the export from the Western Hemisphere of *Hevea* planting material of any sort whatsoever is prohibited by all the South and Central American republics concerned in the development of this new plantation rubber industry, and these embrace nearly all the countries that would be likely to have any such material available. In consequence of this embargo the only sources of new American planting material still open to the Far East are the three Guianas, and possibly Trinidad where some direct importations from Brazil were made early in this century[2].

29. Since all these colonies have political associations with the Far East, one might have been justified in assuming that

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[1] E.W. Brandes (Head Pathologist, In Charge Division of Rubber Plant Investigations, U.S.D.A.) in India Rubber World, 116(4) : 491, 1947.

[2] It is these importations which are considered to have been responsible for the introduction of *Dothidella* into the island (which lies outside the natural range of Hevea), for, as was the case with most other countries in the New World, the bulk of Trinidad's original planting material came from the Far East.

they would be excluded from participation in the Western Hemisphere project. It has recently been reported, however, that the Government of Surinam is collaborating with the U.S. Department of Agriculture in the selection of *Dothidella*-resistant Hevea (Honig, P. Chronica Naturae, *loc. cit.*). In view of the terms of the agreement of the Co-operative Inter-American Plantation Rubber Project (which prohibits redistribution of planting material except to reciprocating agencies and governments of the Western Hemisphere) the position of Dutch Guiana in respect to the N.E.I. is difficult to understand. But, Brandes' remark (in the article already quoted) that because of the present restrictions against export from tropical American countries, resistant material may not now be shipped as a safeguard to the Eastern Hemisphere, suggests that Surinam has agreed to enforce the embargo, and that all legitimate channels of supply have been closed to the Far East.

30. This is the situation which provides the ground for supposing that attempts may be made before long to smuggle budwood into Malaya. As the full significance of the menace of South American leaf disease becomes more widely appreciated, an urge to seek protection through the use of *Dothidella*-resistant material is bound to arise[1], and ways and means will be sought of evading the American embargo. The inevitable result of this tendency will be to create a black market for reputedly resistant seed or budwood in various parts of tropical America; and in order to introduce this material into Malaya the purchaser will be compelled to adopt the same underhand methods as he employed in acquiring it.

31. It will be readily appreciated why many years must elapse before the Malayan cultivations as a whole could be rendered *Dothidella*-resistant. Whether the first material to become available is merely resistant and can therefore be used only for top-budding existing clones, or (and this is less likely) combines resistance with a high-yielding capacity, it will be necessary to test its performance in this country before it can be recommended for general distribution. But this programme of proving will itself occupy at least twelve years—five for the trees to reach a tappable age, five for the tapping tests, and two for the production of sufficient budwood for large scale distribution. Then assuming that replacement of the existing trees is carried out at what is generally regarded as a maximum rate of five per cent of the total acreage per annum, it will take another twenty years to bring the work to completion. It is possible of course that after 15 or 16 years of this process, by which time over a million and a half acres of high yielding material will have come into tapping,

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[1] A suggestion that Far Eastern interests would be well advised to take steps to safeguard their properties by top-budding with resistant clones has already been made in a letter published in an influential American journal, but the writer omits to inform his readers how they are to acquire this material (Bangham, W.N. in Lockwood's Monthly Rubber Report for October, 1947).

production would be sufficient to meet any predictable demand, in which case further replacement would be unlikely to take place. It is to be seen, however, that even on the basis of the most optimistic estimate it cannot take less than twenty-seven years to make the Malayan cultivations *Dothidella*-resistant.

32. Obviously in these circumstances every effort should be made to obtain supplies of genuine *Dothidella*-resistant material with the least possible delay. There appear to be but two ways in which we can set about this object.

(i) By an approach to the U.S. Department of Agriculture. This might be made either to the Division of Rubber Plant Investigations at Beltsville, or to the headquarters of the Department at Washington.

(ii) By advocating the establishment of a station in British Guiana for the selection and testing of *Dothidella*-resistance.

33. The basis for the first suggestion is a belief that the Americans might be prepared to exchange resistant material for budwood of some of the new R.R.I. clones. It may be objected to this proposal that by supplying the New World with this budwood we would in effect be helping to dig our own graves; but this would imply that the success or failure of the American project turns on the possession of these particular clones—a proposition that few are likely to accept. As it is, everything points to the fact that, now the obstacle presented by South American leaf disease has been virtually overcome, the fate of the enterprise will be determined more by the labour supply than anything else. For example, it has been made quite clear in a recent report (O.D. Hargis *et al.* Co-op. Inter-Amer. Plant. Rubb. Development (Colombia). U.S. Dept. Agr., (1946). that a shortage of labour has been primarily responsible for curtailment of the planting programme originally planned by the Republic of Colombia; and it seems more than likely that the existence of this labour problem helps to explain why in 1945, five years after the project had been started, the total area under rubber in all the co-operating countries amounted to only 28,000 acres (E.W. Brandes. Co-op. Inter-Amer. Plant. Rubb. Development (Introduction). U.S. Dept. Agr., 1946).

34. Should the United States Department of Agriculture agree to an exchange of planting material there would naturally be no need to proceed with the suggestion that we should press for the establishment of a test station in British Guiana, but if it was found impossible to come to a satisfactory understanding this would be the only course left open to us. And since there are several difficult questions relating to such matters as finance and administration to be settled before the proposed station can come into being, it would seem that valuable time might be saved if these were brought up for consideration now, rather than postponed until the results of our negotiations with the Americans are known.

35. It is as well to recognise from the outset that a test station in British Guiana will labour under one disadvantage arising from the fact that *Hevea brasiliensis* is not indigenous in

the colony; but this disadvantage is likely to be more apparent than real since wild trees of this species can doubtless be found at no great distance from its unfrequented borders. And again, judging by the few references to the subject that have appeared in the literature, at least some of the *Dothidella*-resistant material used by the Americans has been derived from species other than *brasiliensis*. The pioneer experiments in top-budding carried out on the Ford plantations in Brazil were made with resistant strains of *H.guianensis* and *H.spruceana* (A. Johnston, India Rubber World, 104(3): 48, 1941); and more recently it has been reported that as an outcome of the work now in progress in Surinam, promising material for breeding has been developed from *H.viridis*, a species which occurs between the Rio Negro and the Cassiquiare.

REMEDIAL MEASURES

36. Although it is to be hoped that South American leaf disease will not find its way into this country at any time—but more particularly before the cultivations have been rendered resistant to its attack, ordinary prudence demands that an attempt should be made to formulate some sort of plan for dealing with any outbreak that might occur. Two modes of action are open to consideration; the object of the first being to control the disease by the application of fungicides, and, of the second to eradicate the disease by the systematic destruction of infected plants.

1. *Fungicidal control*

37. Unfortunately it is not possible to regard fungicidal control of the disease in established plantations as a practical proposition. This conclusion is based on economic considerations and not on technical grounds. In fact, comprehensive trials carried out in Panama and Costa Rica have shown that nursery seedlings, and young buddings planted out in the field, can be effectively protected by routine spraying with copper or sulphur fungicides (M.H. Langford, U.S. Dept. Agr. Circ. No. 686, 1947). But bearing in mind the characteristically narrow margin between cost of production and price, it is not unlikely that if an attempt was made to apply these methods to mature areas it would merely be a question which would lead to economic collapse more quickly —loss of yield due to the disease or loss of profits due to the cost of spraying. Similar conclusions have been reached by the Americans. Langford (loc. cit.), while satisfied that the disease could be controlled in established plantations by repeated spraying during the period of annual refoliation, expressed the opinion that the cost of such an operation would prohibit its practical employment.

2. *Eradication*

38. The success of any attempt to eradicate the disease will depend principally on three factors:—(a) the promptitude with which the disease is discovered, (b) the efficacy of the methods employed for the destruction of the infected plants and, (c) the

speed with which these methods can be brought into operation.

(a) *The question of early discovery*

39. Assuming that the disease were introduced on or with *Hevea* planting material (and this is the most probable channel), there is every reason to suppose that it would make its first appearance in a relatively restricted area of young plants. Under such conditions, provided its presence became known soon enough, its eradication should not prove impossible, but everything would depend on action being taken without undue delay—and it is here that we come up against a major difficulty. We know, from its history in the Guianas, how innocuous South American leaf disease may seem when it first appears in a cultivation, so that unless steps are taken to familiarize planters with the symptoms of the disease, and to warn them to be on the watch for it, there is every likelihood that it will have become firmly established before it arouses sufficient attention to lead to its discovery; and then any attempt to eradicate it may well take on the aspect of a forlorn hope.

40. If early discovery of the disease (the *sine qua non* of successful eradication) is to be ensured, the collaboration of a well-informed planting public will be essential, and it is presumably incumbent upon us to create one. But, since it is not easy even for pathologists to identify diseases merely from verbal descriptions of their macroscopic symptoms, it would be foolish to expect the average layman to do so, and it is considered that we must rely mainly on coloured illustrations for instructional purposes. This method has been used with great success by the Ministry of Agriculture for teaching the public in the United Kingdom to recognise the Colorado beetle, and, while it is admittedly easier to memorize the appearance of a strikingly coloured insect than that of a leaf disease, well executed drawings should enable the average person to distinguish the South American disease from any of the more familiar leaf infections. Emphasis is laid on the fact that these drawings must be well executed. A second-rate production (or an impressionistic rendering) might well be worse than useless. Consequently our first step must be to find out whether there is anyone in British Guiana or Trinidad capable of making water-colour sketches of sufficient merit, and it is suggested that the Principal of the Imperial College of Tropical Agriculture be asked to institute the necessary enquiries on our behalf.

41. To choose the most appropriate time at which to distribute these illustrations presents a distinctly difficult problem. Some may favour taking no action until there is definite evidence that the disease has become established somewhere in the Far Eastern region, arguing that too early a distribution will tend to foster a spirit of apathy and indifference. While there is much to be said for this point of view, one cannot ignore the possibility that the first country in the Far East to fall a victim to *Dothidella* might be Malaya itself.

(b) *Methods of eradication*

42. When it comes to the point of deciding what is the best

method to adopt for eradicating a leaf-disease in rubber, one has to turn for ideas to a consideration of measures that have been employed in the past for the eradication of disease in other crops, for in so far as rubber is concerned there is no previous experience to guide us.

43. The introduction of citrus canker into the Gulf States of America on planting material from Japan (an event which took place in the early part of this century) created a problem which was in many respects similar to the one with which we may be faced. The crop involved was a tree (albeit a small one) and the disease (which was of bacterial origin) was extremely contagious, could be disseminated by wind or insects, and attacked leaves, twigs and fruits. It is therefore a matter of great interest to us that its eradication (a feat justly regarded as one of the most remarkable achievements in the history of plant pathology) was accomplished with the aid of flame-throwers.

44. In the successful campaign for the extermination of the common barberry (the alternate host for the black rust of cereals) organised by the United States Department of Agriculture some twenty years ago, use was made of chemical methods, the substances employed being common salt and kerosene. It is questionable, however, whether there is much of value to be learned from this undertaking, for its immediate aim was the destruction not of the parasite but of its alternate host, and in these circumstances there was obviously no objection to the use of slow-acting poisons so long as they were certain in their effects. But we are justified in doubting whether a substance such as kerosene, which could take a matter of months to kill a barberry bush would be of much use to us. On the other hand the possibilities of common salt, which was often effective within a week, might perhaps be worth bearing in mind.

45. With the object of preventing infection of the tubers by *Phytophthora infestans*, and to facilitate lifting, it has become a routine practice in many parts of Great Britain to destroy the haulm just before harvesting the potato crop. As the result of a comprehensive investigation recently carried out by the Agricultural Research Council in collaboration with the Department of Scientific and Industrial Research (Ann. Appl. Biol. 34: 1, 1947), it has been established that the most economical and effective way of " burning-off " the plants is to spray them with solutions of sulphuric acid ranging in strength from ten to twenty per cent. Despite the obvious differences between the two crops, and even more between the grounds for eradicating them, the marked superiority displayed by this phytocide in comparison with the many others that were studied[1] suggests that

[1] Two non-corrosive tar-acid compounds, formulated during the course of this investigation, were reported to be the only sprays tested which approached closely to the level of effectiveness of sulphuric acid. But against these was their cost. Nevertheless, should they become commercially available they would certainly be worth a trial, since for our purpose cost would be a minor consideration.

its use deserves our serious consideration. There is, however, one important objection to it. With so highly corrosive a liquid as sulphuric acid it is necessary to employ special acid-resistant spraying machinery and to provide the labourers with protective clothing. Consequently, unless we were prepared to maintain stocks of the latter (which being, presumably, liable to deterioration would need replacement from time to time), we would be faced with the prospect of being unable to bring the method into operation without considerable delay.

46. Taking all the circumstances into consideration everything points to the use of flame-throwers as the method most suited to our purpose. For apart from the reputation gained by their outstanding performance in the case of citrus canker, no special clothing is needed to operate them, and—what is a matter of no small importance—one should be able to count on obtaining the necessary fuel at any time from the ordinary local sources. Our requirements could therefore be fully met merely by maintaining an adequate stock of the machines themselves in a serviceable condition.

47. While there is little reason to doubt that a way will be found (either by fire or phytocide) of destroying nursery plants and even saplings with the aid of machines of the type that are ordinarily offered for sale, it would be absured to imagine that such equipment could be usefully employed against tall trees. Indeed, it is fairly evident that no ordinary means will suffice to bring about the destruction of a stand of mature rubber (and particular of its leaves) quickly enough to be of any value as a method of eradicating a highly infectious disease. Poisoning with sodium arsenite is far too slow and laborious a process—a month or more may elapse before all the foliage is dead, and thirty-five trees are about as many as one labourer can deal with in a day. Felling, even though it were followed by burning, might well result in a more effective distribution of spores than would normally take place through natural agencies—and this would be the case irrespective of whether it was carried out by manual labour or bulldozers.

48. Spraying from aircraft or the use of specially powerful flame-throwers seem to be the only two methods that hold out any prospects of success. Whether it would be possible to adapt any of the military flame-throwing equipment for this purpose is not known, but it might be worth while instituting enquiries in this direction. Spraying from the air (today the subject of considerable research) is undergoing rapid development not only in America but also in Great Britain and the Dominions. In fact, firms organised to carry out this sort of work on contract are already in operation, and there is no apparent reason why one of these companies should not be prepared to enter into an agreement to undertake the destructive spraying of stands of mature rubber should the need arise. Some preliminary experimental work would of course be necessary, but, once its object was realised and approved, it should be possible to arrange for this to be conducted over areas scheduled for replanting. Information

regarding facilities now available—or likely to become available in the near future, could probably be obtained from the Agricultural Research Council in London or the Council for Scientific and Industrial Research in Melbourne.

(c) *Conditions affecting speed of action.*

49. It is obviously of prime importance that as short a time as possible should elapse between discovery of the disease and the inception of the measures designed to eliminate it. In practice, the extent of this delay will be determined almost entirely by the procedure that has to be followed before destruction of the infected plants can legally begin, and it so happens that the procedure at present laid down by the Agricultural Pests Enactment[1] is quite incapable of dealing adequately with such an event as an outbreak of South American leaf disease. The only section (No. 13) under which a State Agricultural Officer is empowered to order the eradication of a diseased crop (as distinct from a diseased plant) requires him to serve a notice in writing (which may not be issued without the sanction of the Resident) on the proprietor or occupier calling on the latter to carry out the eradication within a specified time. And it is only when the occupier has failed to comply with this notice *within the specified time* that the State Agricultural Officer has authority to enter on the land and carry out the eradication himself. Such a procedure would clearly be unsuitable in the case of an outbreak of South American leaf disease, for, apart from the delay which would result from the grant of a time limit, it may be confidently assumed that the occupier would not possess the equipment necessary to destroy the plants in an effective manner.

50. There is one section of the Agricultural Pests Enactment (No. 17) that would suit the case admirably. This provides that once a pest (a term that by definition includes a parasitic fungus) has been "declared by the Resident to be a dangerous pest by notification in the Gazette", every Inspecting Officer is empowered forthwith to enter on any land within his jurisdiction and take any action deemed necessary to destroy such dangerous pest. Unfortunately, however, this section was framed specifically for the purpose of dealing with an outbreak of locust, and consequently sub-section (i) reads; "If any pest of migratory habit is found to be so numerous in any locality as to become in the opinion of the Resident such a danger to plants of economic value that the safety of such plants cannot properly be ensured by the action of individual proprietors or occupiers, the Resident may by notification in the Gazette declare such pest to be a dangerous pest within the meaning of this enactment, and every Inspecting Officer may then take the measures to control the dangerous pest specified in sub-section (ii)."

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[1] The Enactment referred to here is the F.M.S. Enactment of 1934. Similar (though not always identical) laws were (and presumably still are) in operation in the former Unfederated States and Straits Settlements.

51. By a very slight amendment—involving merely the deletion of the words: "of migratory habit", and: "found to be so numerous in any locality as to become", this section could be made to apply to any pest declared by Gazette notification to be a dangerous pest; for it would then read: "If any pest is in the opinion of the Resident such a danger to plants of economic value etc." It is therefore suggested that Government be invited to consider:—

(a) the introduction of such an amendment to section 17; this to be accompanied by,

(b) the declaration of South American leaf-disease (*Dothidella ulei*, P. Henn.) as a dangerous pest within the meaning of the Agricultural Pests Enactment.

ADDENDA

52. Some modification of section 21 of the Agricultural Pests Enactment may also be considered necessary. This deals with the question of compensation for damage caused by action taken under section 17, and, as it stands at the moment, provides only for payments, not exceeding one hundred dollars in one year, to persons "in needy circumstances". This, of course, restricts its application to the very smallest of smallholders, but apart from this, it would be very surprising if the loss incurred on any one property by the eradication of *Dothidella* did not represent a sum greatly in excess of one hundred dollars. There is, however, another aspect of the matter which needs to be taken into account: if it could be proved that the presence of the disease was due to an illegal introduction of planting material, any claim for compensation would presumably be dismissed. And this brings up the question whether provision should not be made for the imposition of a penalty in such a case.

53. Seeing that South American leaf disease resembles mildew (*Oidium heveae*) in causing what may also be described as a secondary leaf-fall (though of so persistent a character that it ultimately proves fatal), it is felt that Government should be invited to consider amending section 1(d) of the Schedule to the Pest Notification Rules, 1935, (which at present reads: "Secondary leaf fall caused by *Oidium heveae*, Steinm.") to read: "Secondary leaf fall whether caused by *Oidium heveae* Steinm., or any other pest whatsoever". Such an amendment would serve a two-fold purpose; not only would it put South American leaf disease (and, incidently, *Phytophthora* leaf disease) automatically into the category of notifiable diseases (to which of course the former would also belong were it gazetted as a "dangerous pest"), but, since secondary leaf fall of rubber in Malaya may even now be caused by at least three agencies (*Oidium heveae*, the yellow mite, and *Gloeosporium alborubrum*), it would relieve the planting public of the burden of diagnosis by removing what is, from the point of view of disease notification, an undesirable distinction.

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4th February, 1948.

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